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THE FIRE CLAYS AND FIRE CLAY INDUSTRIES OF THE OLIVE HILL AND ASHLAND DISTRICTS OF NORTHEASTERN KENTUCKY.

BY

A. F. CRIDER.

ACKNOWLEDGMENTS.

In the preparation of this report the writer desires to acknowledge the courtesies extended him by the managers of the fire brick companies and the clay operators of this field, who placed at his disposal many of the analyses and tests of clay used in this report.

In the preparation of the technical part of the report the writer has freely drawn on the following reports on clays:

Vol. XI Missouri Geological Survey, by H. A. Wheeler.

The various clay reports of Heinrich Ries.

Vol. V Ohio Geological Survey, by Edward Orton, Sr.

Bulletin No. 2 Mississippi Geological Survey, by W. A. Logan.

Bulletin No. 1, Series IV, South Carolina Geological Survey, by Earle Sloan.

The Flint Fire Clay Deposits of Northeastern Kentucky, Vol. IX, Transactions of the American Ceramic Society, by A. F. Greaves-Walker.

Studies of Flint Clays and Their Associates. Vol. XIV of Transactions American Geramic Society, by Sidney Longman Galpin. The cuts show on succeeding pages of this report were prepared by Doctor Galpin and kindly loaned the writer for this report. They were first used by him in the above noted report.

Various other reports were consulted and reference made to them in the body of this report.

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THE FIRE-CLAYS AND FIRE-CLAY INDUSTRIES OF THE OLIVE HILL AND ASHLAND DISTRICTS OF EASTERN KENTUCKY.

HISTORY.—In the period between 1868 to 1872 Messrs. S. Eifort, K. B. Grahn and J. McL. Staughton bought 10,000 acres of land in the Olive Hill district for the purpose of erecting an iron furnace, and formed a company which was known as the Tygart Valley Iron Company. At that time the Lexington Division of the Chesapeake & Ohio Railroad had not been built from Ashland to Louisville, but was projected, and the above company bought the land expecting the railroad to be built immediately. The projected railroad, however, was not built until 1882.

The erection of an iron furnace, in the meanwhile, was abandoned, and the 10,000 acres of land sub-divided. Mr. Grahn took the eastern portion, in the vicinity of Grahn station; Mr. Eifort took the central part, in the vicinity of Olive Hill; and Mr. Staughton took his allotment west of Olive Hill.

The railroad was finally completed to this section in 1882 or 1883, and Mr. Eifort began to open up and ship fire clay. The first fire clay from the Olive Hill district was shipped by him to the Ironton Fire Brick Works in 1883. The clay when made into fire brick gave such excellent results that its reputation as a refractory clay was established from the first. Fire brick plants from Ashland, Cincinnati, Sciotoville and Louisville were soon getting their clay from this Olive Hill district.

The spirited demand for this clay and the fair prices received for it caused an extensive development and prospecting for and shipping clay became quite an industry for a number of years, and the extent of the clay territory was found to be much larger than was at first suspected.

There are four vital factors that greatly augmented the rapid development of the fire clay industry in this district:

(1) The excellent quality of the clay for refractory wares.

(2) An inexhaustible supply of raw material.

(3) Good railroad transportation.

(4) Proximity to the coking coal district and the iron furnaces of the Pittsburg district.

In 1895 the Olive Hill Fire Brick Company erected the first fire brick plant at Olive Hill. They soon opened the famous "Burnt-House" mine, which contained a solid bed of pure fire clay 27 feet thick. It was the fire brick made of the clay from this mine that established the reputation of the Olive Hill fire brick, which is now sold in all parts of the U. S., Canada, Japan, Cuba and other foreign countries.

In 1900 the Ashland Fire-Brick Company erected a plant on the Chesapeake & Ohio Railroad at Hayward, 9 miles west of Olive Hill. The plant has seven kilns and a daily capacity of 10,000 to 12,000 bricks.

The following year, 1901, the Harbison-Walker Refractories Company completed their plant at Olive Hill. It is one of the largest plants south of the Ohio river.

In 1903 the Kentucky Fire Brick Company established a plant at Haldeman, on the Chesapeake & Ohio Railroad, in Rowan county, near the boundary line between Rowan and Carter counties. The plant has 14 kilns and a daily capacity of 40,000 to 50,000 bricks.

The third plant in Olive Hill was built in 1910. It is owned by the Olive Hill Calcine Company, and is engaged in the production of calcine which is used principally in the manufacture of glass pots. Calcine for this purpose is made from the highest grade flint clay.

Mr. Grahn, soon after the completion of the Chesapeake & Ohio Railroad to Louisville, opened up a clay mine on his property at Grahn and shipped the clay to the Louisville Fire Brick Works at Louisville, with which he was connected.

The Louisville Fire Brick Works is now completing a 7-kiln brick plant at Grahn station on the Chesapeake & Ohio Railroad, 5 miles east of Olive Hill.

Still another fire brick plant will have been completed in this district before this report reaches the press. The plant is located at Hitchens at the junction of the Chesapeake & Ohio and the Ohio & Kentucky railroads. The plant is said to be the largest fire brick plant in the world. It is ten 30-foot kilns of 80,000 capacity and it is the

purpose of the company to build ten additional kilns which will give an output of 100,000 brick a day.

There are two fire brick plants in Ashland, owned by the Ashland Fire Brick Company, and one near the mouth of Tygart creek at McCall P. O., owned by Chas. Taylor Sons, all of which come within the territory covered by this report. The Ashland plants get their best grade of clays from their mine at Hayward, in the Olive Hill district. The second grade or highly plastic clays are obtained from the Coal Measure clays near Ashland. The clay for the Taylor plant comes from the Olive Hill clay belt.

CHAPTER I.

THE TWO DISTRICTS DEFINED.

The area included in this report, on account of the difference in the origin, the quality and the geological age of the fire clays, is divided into two districts. For convenience of reference these will be discussed under the heads, Olive Hill district and the Ashland district.

The Olive Hill district includes the plastic and the flint fire clays, which are associated with the Mississippian limestone, the uppermost member of the Sub-Carboniferous series in this region.

The Ashland district includes the higher fire clays that are found in the Coal Measures in Carter, Greenup and Boyd counties. These Coal Measure fire clays are found at different horizons, but the most prominent beds are those occurring near the horizon of the Ferriferous limestone.

The Coal Measure rocks are younger than those in which the Olive Hill fire clays occur so that from a geographical standpoint alone there is considerable overlay in the two districts, but the clays of the two districts are so distinct in character that the geological division is very apparent.

AREA OF THE OLIVE HILL DISTRICT.

The Olive Hill district includes approximately the western half of Greenup, the western half of Carter, the

eastern and southeastern parts of Rowan, and the northwestern part of Elliott counties. There is a narrow belt of territory along the border of Lewis county near the crest of the ridge which forms the boundary between Lewis and Carter counties, where isolated deposits of the clay are found; but the rapid rise of the strata to the northwest soon carries the clay above the tops of the hills.

The district from northeast to southwest is approximately 12 miles wide, and it extends from the Ohio river in a southwesterly direction to the North Fork of Licking river, a distance of about 55 miles, and includes about 660 square miles.

Tygart creek from its headwaters in the extreme southwestern part of Carter county to its mouth, two miles above Portsmouth, follows approximately the center of the fire clay district.

EXTENSION OF THE OLIVE HILL FIRE CLAY BELT.

A fire clay of the same geologic age and origin as the Olive Hill fire clay is found in Ohio and is an extension of the same clay belt as the one in Kentucky. It occurs along the western border of the Ohio coal field in Scioto, Jackson, Hocking, Perry and Muskingum counties.* It has long been mined in the hills back of Sciotoville, and was first known as the Sciotoville fire clay. It is also known in Ohio** as the Logan clay from Logan, in Jackson county, where it has been extensively worked.

There is a possibility of finding small deposits of the same clay at the base of the Coal Measure rocks southwest of Licking river in Morgan, Menifee, Wolf and the other counties in Kentucky skirting the western rim of the eastern coalfield.

AGE OF THE OLIVE HILL FIRE CLAY.

The relation of the fire clay to the other geologic strata of the district has a special significance to the prospector in locating the clay where it does not appear at the surface. The nature of the rocks overlying, and

*Edward Orton, Jr., Ohio Geological Survey, Vol. VII.
**Ibid.

to some extent the rocks beneath, may, as will be more fully explained later, largely determine the character of the clay.

The Olive Hill fire clay, as previously stated, is found associated with the Mississipian limestone. Where the limestone is present the normal position of the clay is on top of the limestone, but in places the limestone has entirely disappeared and the fire clay rests on a bed of pinkish-colored clay which is the remnant of the decomposed limestone. The fire clay is never found in its normal position except where the limestone is now present or was present before its dissolution. In many places, however, the clay has been carried out of its normal position, on top of the limestone, and redeposited as local deposits in the Conglomerate.* An instance of this kind is on the Olive Hill Fire Brock Company's land on Perry's branch just outside of Olive Hill. Here a deposit of fire clay was found 30 feet or more above the base of the Conglomerate sandstone. It was a basin-shaped deposit about 100 feet long by 50 feet wide and 3 to 6 feet thick. The clay was of excellent quality and was worked out by the Olive Hill Fire Brick Company.

Another similar deposit was found about one mile east of Carter on the property of Joseph Pence. Here a deposit of flint clay has been opened 20 to 30 feet above the base of the Conglomerate, which latter forms a high cliff around the hill.

Still another deposit of the flint clay above the base of the Conglomerate was found on Andy White's branch just below Elliottsville, in Rowan county.

There is a marked unconformity between the Mississippian limestone and the Conglomerate. At the close of the deposition of the limestone the deep sea bottom, on which the limestone was formed, was lifted above the surface and was subjected to the eroding action of atmospheric agencies. This erosion interval was continued long enough for the full thickness of the limestone, which in places is still found to be 125 feet thick, to be in some points entirely worn away. At other points only a small

*The sandstone under the fire clay mentioned in this instance and in the following places is here called a part of the Conglomerate. Further investigation may possibly prove this to be a separate sandstone belonging in the series below the Conglomerate, possibly a Chester sanstone.

portion of the limestone was eroded so that we may now find the Conglomerate resting on the limestone, on the clay, or perchance both the clay and the limestone are gone and the Conglomerate rests directly on the Waverly.

ORIGIN OF THE OLIVE HILL FIRE CLAY.

It is to be understood in discussing the origin of any clay that while the primary source is from the decomposition of feldspathic rocks, the direct source may be readily traced to the disintegration of limestones or shales. In the discussion of the origin of the Olive Hill fire clays we shall confine our remarks to the direct source of these deposits.

The origin of the Olive Hill fire clays has given rise to much speculation among the clay workers of this field, and has an important relation to similar deposits in other parts of the country.

All clays are formed in one of two ways. (1) By disintegration and solution of rocks in place, or, (2) by the transportation and the deposition of clay particles in water. The first class is called "residual deposits;" the second class is known as "sedimentary deposits."

Residual clays may be formed from igneous rocks where the transition from clay on top to the unaltered parent rock below is gradual. They may also be formed from the dissolution of limestones in places where the calcium carbonate is attacked by the surface waters leaving behind the insoluble aluminum silicates.

There are no feldspar igneous rocks in Kentucky, so the fire clays of the area under discussion could not have been formed from the disintegration of such rocks in place.

From the association of the fire clay deposits with the Mississippian limestone below and the Conglomerate sandstone above and the absence of feldspathic rocks in this region, there is meagre evidence to show that the clay is a sedimentary product which has been directly carried by streams from the area of disintegrating feldspathic rocks. If such were the case there would doubtless be a large percentage of feldspar, quartz and iron interbedded with the kaolinite. The clay is found in beds from a knife edge to 27 feet in thickness and con-

tains a relatively small amount of feldspar, quartz, iron and other injurious substances.

There are only two other possible sources of the clays under discussion. These are (1), the disintegration in situ, of the sedimentary rocks found in the district, and (2), a redeposition of the clays formed from the breaking up of these sedimentary rocks. The evidence is conclusive that a part of the fire clay deposits of the Olive Hill district has been formed from decomposition and solution of the Mississippian limestone in place. The other deposits have been formed as a redeposition product from the breaking up of limestone and flint clays.

If the clay is a residual product derived from the limestone the question as to whether the clay was formed previous to or subsequent to the deposition of the Conglomtrate naturally presents itself. There is no perceptible difference in the quality of the clay which occurs on top of the ridges and is subjected to the action of surface waters and that found buried beneath 250 feet of impervious shales and other rocks. It is evident, therefore, that the clay reached its present condition before the deposition of the Conglomerate. It is hardly possible that thick deposits of residual clay, such as are found in this district, could be formed except by the action of surface waters.

The insoluble residue resulting from the chemical dissolution of the limestone of the Olive Hill district when first formed was doubtless more or less plastic. Some of the clay is still found in this condition, but there is a large percentage of the non-plastic flint variety. In some of the mines almost the entire thickness of the vein is composed of flint clay. In other openings a portion of the vein is plastic and the remainder is flint or semi-flint. There is generally present a bed of plastic, pink calcareous clay below the flint clay and resting directly on the limestone.

The flint clay has not all the same origin. In some parts of the district where the clay has been deeply covered by later formations the clay was originally formed as residual plastic clay, and was subsequently re-crystallized in situ, into the form of flint clay.

In all sections of the district there are deposits of flint clays that have not been formed by a re-crystallization of the residual plastic deposits in place, but are residual clay deposits that have been broken up and washed into basin-shaped depressions forming an accumulation of sedimentary clays. They were subsequently re-crystallized into flint clays in much the same manner as the flint clays, described above. They are to be distinguished, however, as "residual flint clay" and "transported or sedimentary flint clay." The latter deposits contain a rim of free silica on the edges and bottoms of the basins. All of the deposits found in the Conglomerate and some below the Conglomerate are of the latter class.

There is sufficient evidence at hand to show that all of the clays of the district do not have the same origin. The flint clays which are found overlying the pink, calcareous clay most generally are derived from the underlying limestone. The limestone was first changed into the calcareous clay which later lost its lime content and was re-crystalized into the flint.

The following is a summary of the evidence secured in the study of the clays indicating the sedimentary origin of some of the Olive Hill fire clay deposits. (1) The presence of leaf impressions in some of the clays; (2) The even surface of the top of the deposits; (3) The presence of sand grains in some of the clays; (4) The presence of angular fragments of undecomposed flint clay in some overlying deposits; (5) The presence of lenses of sandstone, known to the miners as "silica boulders," in some of the mines; (6) The presence of stratification lines in at least one deposit of a very hard flint clay; (7) Local basin deposits of flint clay found in the Conglomerate 20 to 30 feet above the top of the Mississippian limestone.

The following facts are cited as conclusive evidence of the residual origin of a large per cent of the boulder flint clays: (1) The association of the clay with the Mississippian limestone as shown in figure 5; (2) The presence of a calcareous clay, known by the miners as "pink eye," between the flint clay above and the limestone below. The limestone was first changed to the pink eye

which gradually lost its lime content and was re-crystalized into the flint; (3) The lack of a thin rim of sandstone on the bottom and the edges of the flint clay deposits as is the case of the Missouri flint clay deposits*; (4) The oolitic structure of some of the flint clays some of which, by merely looking at them, may easily be mistaken for a piece of oolitic limestone. In this case the calcium carbonate has been leached out and replaced by silicate of alumina leaving the original structure of the limestone.

The decomposition of limestones in situ has doubtless been the origin of more deposits of kaolin and highly refractory clays than was formerly supposed. A large percentage of the kaolins, and the plastic fire clays of Missouri** were formed directly from the weathering of limestones.

In discussing the origin of the Missouri kaolin, page 162 of the above noted report, Mr. Wheeler says: "The granite and porphyry areas of the southwestern part of the State which occur surrounded by the limestones carrying the kaolin do not furnish any workable kaolin deposits, as the clay resulting from their decay has thus far been found to be too impure with iron to answer for chinaware. This is a remarkable and quite unusual phenomenon for so extensive a district where both feldspathic igneous (plutonic) rocks and sedimentary limestones occur, to have such large deposits of kaolin derived from the limestones, and none from the plutonic rocks. Yet the evidence is conclusive that the Missouri kaolin deposits thus far opened have been derived from the decay and solution of limestones which have left behind, as the insoluble impurities, beds of clay and large bodies of chert fragments as mere remnants of their former great mass."

As to the origin of the flint clay deposits he adds: "Occasionally the residual clay has been washed into choked sink-holes or closed basins, where there results an accumulation of the fire clay as a sedimentary deposit. Often the depressions are completely filled by the local washings from the adjacent limestone. This is the origin of the ball and flint clay deposits. In this case only the

*See quotation from Wheeler's Report.
**Mo. Geol. Survey, Vol. XI.

fine clay is carried into the basin and it is free from the chert that is so largely intermixed through the 'hill' or residual deposits.''

The fire clays* of Hart, Larue, Taylor and Edmonson counties, Kentucky, are associated with the Chester and the St. Louis limestones of that region, and probably have a similar origin to the Olive Hill fire clays. Mr. Gardner** is of the opinion ''that the majority of the clays of the district are of marine origin, having been carried probably by rivers from a great distance.''

It is known, however, that there is an unconformity in the district described by Mr. Gardner at about the horizon where the fire clays are found. It seems more probable, therefore, that the clay was formed in the same manner as the Olive Hill and the Missouri clays.

In a private letter from Mr. Richard R. Hice, State Geologist of Pennsylvania, as to the origin of the refractory clays of that State, Mr. Hice says: ''There has been no connected study made of the clays of Pennsylvania, especially that portion of Pennsylvania (referring to the Clearfield County clays) or of the flint clays in any portion of Pennsylvania. The matter of the origin of flint clays is a complicated one when one considers the conditions under which we find flint clay in the different portions of this country; we cannot but think that the origin has been the same in all cases.''

''In this State (Pennsylvania), we find the flint clays in the Pottsville sandstone, in the under-clays of the Allegheny river series, and sometimes in other sandstones. In the under-clays we sometimes find them forming the bottom of the clay vein, and at other times a distinct belt in the clay with a rather definite position in the vein; again in the top of the vein and very frequently scattered irregularly through the entire thickness of the clay vein. The well known Boliver clay has sometimes been correlated with the Upper Freeport under clay. This, however, is a mistake, as it occupies the horizon of the Upper Freeport limestone, which is below the clay horizon; and when the clay is present, the limestone is absent, at least this is the general rule and I recall no exception.''

*Kentucky Geological Survey, Bull. 6. 1905.
**Ibid.

In discussing the geologic age of the flint clays of Clearfield County, Pennsylvania, George H. Ashley in Bulletin 285, United States Geological Survey, says: "Flint clay occurs at four horizons—three in the Allegheny, which appear to be of rather limited distribution and minor importance, and a fourth at the Mercer horizon in the Pottsville formation. The Mercer coal is underlain by flint clay, which at present is the principal bed being mined in Clearfield County."

The Mt. Savage,* Maryland, fire clays which have an established reputation as highly refractory materials occur in the Pottsville formation below the Homewood sandstone and above a heavy Conglomerate sandstone.

The most important flint clay deposit of Tuscarawas County, Ohio, is that which occurs near Strasburg at the horizon of Newberry's** No. 7 coal, which is the probable equivalent of the upper Freeport coal.

It is evident, that the stratigraphic position of the Olive Hill flint clay is lower than the Strasburg, Mt. Savage and Pennsylvania flint clays.

PETROGRAPHY OF THE OLIVE HILL FIRE CLAY.

A very interesting and helpful petrographic study of plastic and flint fire clays has been made by Sidney Longman Galpin of Cornell University and first printed in Transactions American Ceramic Society, Vol. XIV., 1912. Petrographic sections of the above mentioned flint clays and their associates were studied and compared. The following are the results of Mr. Galpin's studies of sections from Olive Hill, Kentucky.

"The samples examined represent (1a) typical flint clay; (1b) top of flint clay bed; (2) the semi-flint; (3) the aluminite varieties described by Greaves-Walker. All are found in or near the Burnt House mine.

(1a) (SPECIMEN No. 21). This is of buff color and shows a good conchoidal fracture. Small concretion-like spots may be seen. It is very similar in appearance to some of the Clarion, Pa., flint clays. Fractures in this clay are frequently lined with small plates of barite.

*Md. Geol. Survey, Report on Allegheny County.
**Ohio Geological Survey, Vol. III.

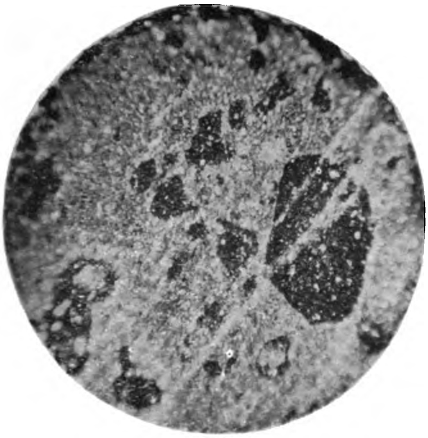


Fig. 1—Semi-hard clay, Olive Hill, Ky., by direct light. Shows cloudy areas which may represent weathered feldspars. x80.

Fig. 2—Flint clay, Mt. Savage, Md., between crossed nicols. Shows development presumably by hydro-micas along a slip plane. x160.

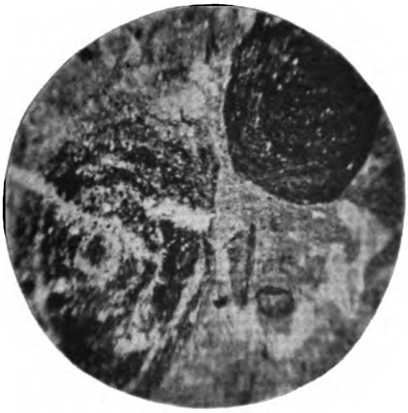


Fig. 3—So-called "Aluminite" from Olive Hill, by direct light. Shows structure of oolites. x80.

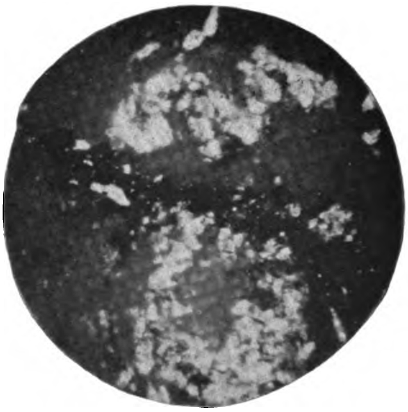


Fig. 4—Section of aluminite from Olive Hill, between crossed nicols. Shows hydrargyllite (gibbsite) recrystalized in central part of the oolite represented in Fig. 3. x200.

(1b) (SPECIMEN No. 20). This clay is darker than No. 21 and shows its resemblance to the typical flint clay.

(2) (SPECIMEN No. 22). A smooth, buff-gray clay cut up into interlocking lenses by slickensides. The central parts of these lenses are like the flint clay.

(3) (SPECIMEN No. 23). The aluminite is a buff or pinkish rock of great toughness having a sharp but rough conchoidal fracture, the surfaces studded with oolites like those seen in bauxite, but of small size and seldom exceeding 1 mm. in diameter.

SECTION XX. Clay from the top of the flint clay, Olive Hill, Kentucky.

Structurally this clay is similar to No. XI. from Clarion, Pa. It is, however, richer in carbonaceous matter, which, along the cracks that served as pathways for solutions, had precipitated iron in the form of pyrite. Scattered through the clay are cloudy areas sometimes of circular outline and occasionally bearing remarkable likeness to the cross sections of feldspar fragments. (Plate IV., Fig. 2).

Crystallization of kaolinite prisms has formed clear patches in some of these areas, often producing radiate structures within, and more frequently about the periphery of the cloudy area. (Fig. 7.)

Types of structures characteristic of Olive Hill, Ky., clays.

(a) An irregular mass of kaolinite prisms developed toward the center of a cloudy oolite.

(b) Kaolinite grains or prisms producing radiate structure within oolite.

(c) Radiating kaolinite crystals bordering an irregular clouded spot (possibly a weathered feldspar fragment).

"Kaolinite is the most common mineral although hydro-micas are to be seen, especially as ribs in the kaolinite."

"Quartz, rutile, zircon and tourmaline are present in lesser amounts."

SECTION XXI.—Flint clay, Olive Hill, Ky.

"This section closely resembles No. XX. in mineralogical character, but is free from pyrite and contains much less carbonaceous material, and the structure is

like that described in Section XI. [The typical flint clay from Clarion, Pa.] "There are traces of a sort of 'mares tail' arrangement in the parts least crystallized. These structures are cut by the concretionary and cloudy areas. It is thought possible that these structures were formed by movements during contraction of the colloidal jel, of which the clay was largely composed, as some of the water was squeezed from it by the weight of accumulating sediments above. Traces of such structures are to be found in all of the very fine-grained flint clays."

"Kaolinite prisms (up to 70 microns length) show a great variety of bent and contorted forms. 'Ribbing' by hydro-micas is a prominent feature and is apparently responsible for much of the warping in the kaolinite prisms. Muscovite is practically absent."

"Quartz may be seen in widely scattered corroded grains up to 400 microns diameter. Other accessory minerals as are noted in other sections."

"SECTION XXII.—Prepared from powder of semi-flint clay, Olive Hill, Kentucky.

"This section shows largely individual plates, but also many aggregate grains, indicating that the development of hydro-micas in this clay is not as complete as in some of the semi-flint clays from other localities, for the development of hydro-micas seems to accompany any movements in the clay which tend to loosen up the individual plates, resulting in more complete disintegration into individual grains upon grinding."

"The main mineral seen is hydro-mica. No kaolinite was identified, but is doubtless present to some extent."

"Muscovite is not common, and the same is true of quartz and the other common accessories."

SECTION XXIII.—Highly aluminous flint clay. Olive Hill, Kentucky, the aluminite of Greaves-Walker.

"Here one sees numerous concretions of oolites (Plate V., Fig.1) scattered through a fine-grained ground mass, which is similar to that of Sections XX. and XXI., but for fewer kaolinite prisms and occasional patches of mineral grains which show a higher index than kaolinite, and a structure differing somewhat from that of mica. Careful determinations of elongation, extinction and birefringence together with comparison to known hy-

draryglite (gibbsite, (Al $(OH)_3$) lead to the conclusion that these bunches are composed of grains of that mineral (Page V., Fig. 2). It is more common in the oolites than in the ground mass. Here it is seen in nucleal groups and concentric bands separated by rings of cloudy, extremely fine-grained material which may be a bauxite mixture."

"Kaolinite prisms are rare in the oolites, but are closely associated fith the hydrargyllite in the ground mass. The hydragryllite may represent the recrwstallization of hydrous alumnia which was present originally in the sediments."

"This clay seems to represent an intermediate phase between kaolin and bauxite."

"Dehydration of the Olive Hill clays gave the following results:"

"Dehydration Tests of Olive Hill, Kentucky, clays.

	Per cent loss at 112°C.	Per cent ignition loss.	Total per cent loss.
21. Flint clay	0.82	13.2	14.00
22. Semi-flint	0.96	11.7	12.7
23. 'Aluminite'	0.4	13.0	13.4

"The semi-flint shows similarity in water content to the 'Mt. Savage' (Md.) flint and the 'woodland' (Pa.) 'soft clay.' "

"The aluminite, despite the lower amounts of kaolinite to be seen, shows a fairly high water content due to the presence of some hydrargyllite (Al $(OH)_3$)."

Knote in experimenting on the chemical and the physical changes in refractory clays due to the influence of heat gives the fire-shrinkage, apparent specific gravity, and porosity curves of refractory clays from Olive Hill, Portsmouth, Ohio, McKeesport, Pa., Clearfield County,, Pa., Mt. Savage, Md., Mineral City, Ohio, and an imported German plastic glass pot clay.

At cone 23 the results are given in the following table:

	Per cent. Fire shrinkage	specific Apparent gravity.	Per cent Porosity.
Olive Hill flint clay	9.5	2.71	14.0
*Olive Hill plastic clay	8.6	2.44	2.0
Portsmouth Ohio, flint clay	9.5	2.71	14.5
McKeesport, Pa., flint clay	9.5	2.62	15.5
*McKeesport, Pa., plastic clay	4.3	2.14	2.0
*Clearfield County, Pa., flint clay	5.0	2.52	18.5
Clearfield County Pa., plastic clay	7.0	2.56	12.0
*Mt. Savage, Md., flint clay	3.6	2.53	28.0
Mineral City, Ohio, flint clay	7.0	2.54	27.0
German Plastic Glass Pot Clay	4.2	2.21	2.0

*Trans. Am. Cer. Soc., Vol. XII.

The results for the German clay are given at cone 15. The clay became vesicular between cones 15 and 20.

In the list marked with a star (*) the shrinkage was greater between cones 11-15 than it was at cone 23. There was in these cases an actual swelling of the clay after it reached its greatest shrinkage at cones 11 to 15 to the end of the test at cone 23.

As may be expected, the flint clays showed less porosity than the plastics, due to greater amount of water in the latter than in the former.

The results obtained by Knote were determined on burned briquettes. Cone 11 is the equivalent of 2,462 degrees F., or 1,350 degrees C. Cone 23 corresponds to 2,894 degrees F., or 1,590 degrees C.

It may be interesting here to compare the melting points* of firebricks and clays as recently determined by the Bureau of Standards. The following determinations were made:

	Degrees		Centigrade
Fire clay brick	1555	to	1752
Bauxite brick	1565		1785
Silica brick	1700		1705
Chromite brick	....		2050
Magnesia brick	....		2165
Kaolin	1735		1740

*Journal of Franklin Institute, Feb., 1913.

	Degrees	Centigrade
Bauxite	....	1820
Bauxite clay	....	1705
Chromite	....	2180
Pure alumina	....	2010
Pure silica	....	1750
Carborundum	....	2700

Pure silica does not melt at 1,750 degrees C., but flows or is distinctly viscous at that temperature.

While the melting point of fire bricks is given at 1,555 to 1,725 degrees C., the individual clays composing the mixture melt at a much higher temperature. This is shown by the fact that a number of tests of the Olive Hill clays, where taken separately, were not melted until a temperature of 1,810 to 1,830 degrees C. was reached. It may be said, however, that the determinations were made by Seger cones, which is only approximate."

CHAPTER II.

GEOLOGIC OCCURRENCE OF CLAYS.

Carboniferous System.	Pennsylvanian Series.	Monongahela formation.	
		Conemaugh formation.	
		Allegheny formation.	
		Pottsville formation.	
			Unconformity.
		Olive Hill fire clay horizon.	
			Unconformity.
	Mississippian Series.	Mississippian limestone.	
			Unconformity.
		Waverly.	

The fire clays of the district under consideration are so intimately connected with and dependent on certain

of the geologic formations that a brief description of their geologic and geographic distribution will be given.

The surface of the area was originally a plain higher in the south and inclined northward to the Ohio river. The larger streams have cut their channels rapidly into the strata leaving in many places very precipitous cliffs adjacent to the streams. The crests of the hills in the southern and the western parts of the region rise to about 1,150 feet above sea level. At Portsmouth, Ohio, which is opposite South Portsmouth, Kentucky, the low water mark in the Ohio river is 468 feet above sea level. The difference in the extremes of elevation in the district is, therefore, about 682 feet. The region as a whole is very rugged, the hills rising on an average 400 feet above the main stream bottoms. The bottoms are comparatively narrow, except along the Ohio river, Little Sandy river and the lower part of Tygart creek.

The region is occupied by the Mississippian, Pennsylvanian and Recent strata, all of which, except the Recent, dip east and southeast. The general dip of the rocks west of Little Sandy river ranges from 10 to 40 feet to the mile, with an average dip of something like 25 feet to the mile. East of Little Sandy the dip is less regular. While the general dip is to the southeast there are numerous local folds which have given rise to the accumulation of more or less oil and gas.

The general surface effect of the rapid east and southeast dip of the strata is to cause the older formations to successively disappear below drainage and the younger rocks to occupy the surface.

Ohio river forms the northern boundary of the region under discussion. Tygart creek and its tributaries drain the western, Little Sandy the central, and Big Sandy the eastern areas. That part of the district which lies in Rowan county is drained by the waters of the North Fork of Licking river.

It is a very noticeable fact that the streams entering Tygart creek from the west are much larger and more numerous than those entering from the east. This is to some extent true of Little Sandy river though it is not so marked. The streams flowing east and southeast flow with the dip of the rocks and for that reason they eat

into the divide, gradually pushing it farther from the main stream. The streams on the east side flow across the strata, which, to a great extent, retards the action of the streams.

MISSISSIPPIAN.

WAVERLY.—The upper sandstones and shales of the Waverly are the oldest rocks found in the area under discussion. They are found on Tygart creek and its principal tributaries from Triplett tunnel to the Ohio river, on the upper waters of Big Sinking and on the main streams of Rowan county. The clays of this geologic age consist of shales, which are often suitable for paving brick and face brick. The paving brick plant on Indian Run, 4 miles southwest of South Portsmouth, is using the shales of the Waverly in the manufacture of paving brick.

The thickness of the Waverly above the surface in the vicinity of Morehead is about 400 feet. In the vicinity of Olive Hill its thickness above surface is only about 50 feet.

MISSISSIPPIAN LIMESTONE.

The uppermost member of the Mississippian in this territory is represented by a massive limestone that is known in the Kentucky Geological Survey reports as the "Sub-Carboniferous limestone." It is the equivalent of the Maxville limestone in the Ohio reports. The upper part of the limestone forms the floor on which the fire clays of the Olive Hill district rest.

The limestone is found in practically the same territory where the Waverly occurs, and extends a few miles farther east on Big Sinking. It is exposed in the stream bottoms of Gorman Fork from Cory to the mouth of Dry Fork; on Barretts creek; Everman's creek, Carter county; and North Fork of Oldtown creek, Greenup county. East of this the dip carries it below the surface where it is struck in oil and gas wells as far east as Ashland.

The thickness of the limestone varies from the thickness of a knife edge to about 130 feet. The latter thickness was obtained at the rock crusher on Smith's creek, two miles above Carter City, Carter county. The limestone on Tygart creek below the mouth of Big White Oak creek is very irregular in thickness and in some localities it is entirely wanting.

The irregular thickness is due to the fact that the limestone was subjected to an erosion interval previous to the deposition of the Conglomerate. In places the entire thickness of the limestone was removed; in other places only a part was removed.

The fire clay deposits of the Olive Hill district are associated with and owe their origin to the Mississippian limestone which forms the floor on which the clay rests.

PENNSYLVANIAN.

The Pennsylvanian is represented by the Conglomerate sandstone, clays, shales, coals, massive sandstones and limestone. No attempt will be made in this report to separate the Pennsylvanian into its usual subdivisions. The basal member of the Pennsylvanian, the Conglomerate, rests unconformably on the Mississippian limestone. In some of the clay mines there is a bed of black shale between the Conglomerate sandstone and the Olive Hill fire clay, in other places the shale is absent, the Conglomerate resting directly on the clay.

At Cory near the headwaters of Gorman Fork of Little Sinking there is evidence of a decided unconformity at the base of the Conglomerate sandstone. This is a different unconformity from the one at the top of the Mississippian limestone as there is something like 40 to 50 feet of shale here on top of the limestone. At other places farther down the same branch the Conglomerate comes down to and rests directly on the fire clay. Fig. 1 shows the relation of the Conglomerate to the underlying shale.

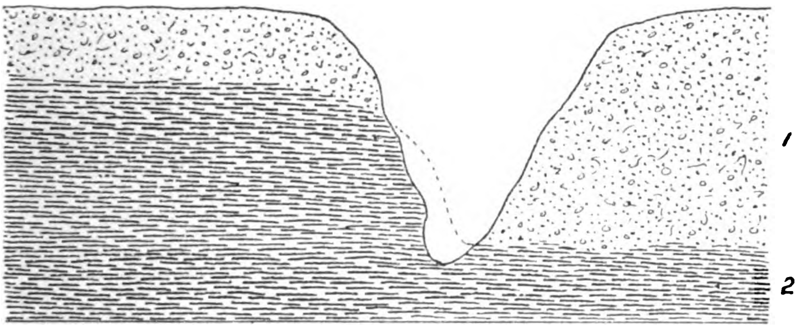


Fig. 1.

Showing erosion of shale previous to deposition of conglomerate.
1. Conglomerate.
2. Shale.

It is a noticeable fact that over a large area where the Olive Hill fire clay is present, the Conglomerate sandstone is absent. This may be due to a lack of deposition; but it is more probable that the Conglomerate was deposited and subsequently eroded.

The Pennsylvanian rocks, except in a few localities along some of the stream valleys between Little Sandy and Tygart, form the surface of the entire country east of Tygart creek. West of Tygart creek they form the tops of the hills as far west as the divide between the waters of Tygart and Kinniconick. They also form the tops of the hills in southeast and southern Rowan County.

There are two horizons in the Pennsylvanian rocks where clays are now being worked. The lowest bed of clay comes just below coal number 4, which is the first coal below the heavy bedded sandstone that forms the high cliffs between Ashland and Catlettsburg. This sandstone is called "Homewood sandstone" by Phalen in Bulletin 349 U. S. Geological Survey.

The upper and most important clay deposit on account of its quality, extent and thickness is associated with the Ferriferous limestone. It has been or is now being worked at Willard, Hitchins, Denton, Music and Ashland. These various deposits will be described in detail later.

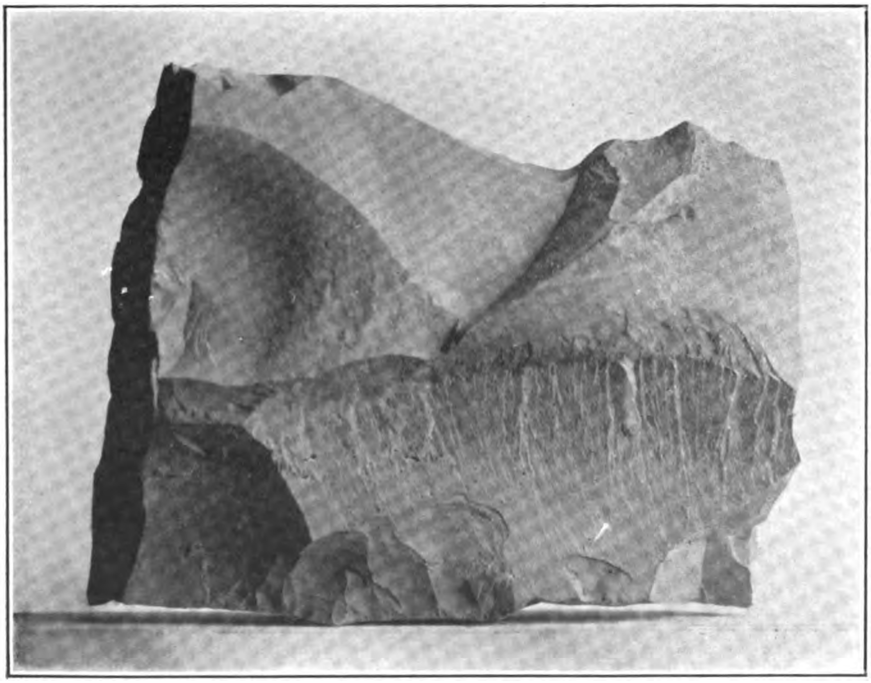
RECENT.

The Recent deposits consist of the alluvium of the streams. It is found extensively on the flood plains of the Ohio, Little Sandy and the lower waters of Tygart creek, and to a less extent on many of the smaller streams. On a large number of the streams the gradient is so great that there is very little flood plain deposit.

CHAPTER III.

THE OLIVE HILL DISTRICT.

The Olive Hill fire clay district is the most important one in Kentucky. It has a large area underlaid by high grade refractory clays that are now being mined and a still larger area untouched. There are now six large fire brick plants and one calcine plant in the district and four others in the State using clay from this



Olive Hill Flint Clay, showing conchoidal fracture.

district. In addition a large amount of raw clay is shipped to fire brick plants, potteries, glass pot works, etc., in Ohio and Pennsylvania. The production of fire brick, clay and calcine in Kentucky for 1911 is valued at $989,606.00, most of which is from this district. The fire clay industry in this region is yet in its infancy. Two new plants, included in the above statement, will have been completed before this report reaches the press and others are projected.

Practically the only development that has been made of the fire clays has been along the Lexington Division of the Chesapeake and Ohio Railway from Ashland to Morehead, and on the main line of the Chesapeake and Ohio from Ashland to Cincinnati. There is a large area between Olive Hill and Elliottville, on the upper waters of Tygart and Big Sinking, that is underlaid by an excellent quality of plastic and flint fire clays.

Another extensive area of undeveloped clay lies between Olive Hill and Soldier, north of the Chesapeake and Ohio Railway.

Thick deposits of clay are also found on the west side of Tygart from Olive Hill to the Ohio river and to some extent on the east side of the same creek, especially in the hills facing the Ohio river north of Greenup. However, the clay found in the lower half of the Tygart drainage is found to possess more iron and other impurities than the clays of the upper waters. While this as a general thing is the rule, there are exceptions to this statement.

OLIVE HILL FIRE BRICK COMPANY.—The Olive Hill Fire Brick Company in 1895 established the first fire brick plant in Olive Hill district. It is located on the Chesapeake and Ohio Railway at the mouth of Perry's branch in the western edge of Olive Hill.

Soon after the plant was built the "Burnt House" mine was opened which supplied clay for the plant until recently. The mine was located on Perry's branch about one mile north of the plant. The clay was hauled to the mine over a narrow gauge railroad in small cars drawn by a "dinky engine." This was one of the most remarkable fire clay deposits that has been opened in the district. It was the fire brick made of the "Burnt House"

mine clay that established the high reputation that the Olive Hill fire brick has since enjoyed.

The clay in this mine would average about 16 feet in thickness, but in places it was 27 to 30 feet thick.

A. F. Greaves-Walker, in Volume IX, Transactions of the American Ceramic Society, gives the following description of the Burnt House mine when it was being operated:

"Five different and distinct kinds of clay make up this vein, showing fire clay in all of its forms, from plastic to its very hardest condition. On the sandstone bottom lies the 'semi-hard,' 'semi-flint' or 'hard soft,' as it is variously named. This is a clay apparently in the transition state between a plastic and a flint. It is not really plastic, but being given a wet pan treatment, it will develop a good deal of plasticity, enough to bond itself. On exposure to the atmosphere, it slakes into sharp cornered cube-like masses, yet it breaks with an even rock fracture instead of an even conchoidal one. It occurs through the whole vein and ranges from a few inches to 20 feet in thickness.

"It occurs in a number of colors, white, buff, red, black, gray and gray-spotted with red. These colors are due to vegetable matter and burn out, leaving a clear cream color. It is not easily shot, as it is full of 'slick seams,' showing movement of the bed when the clay was in a more plastic condition."

"Following are several analyses of semi-flint from Burnt House Mine:

TABLE No. 1.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Silica	44.52	43.56	43.82	42.29	53.07	50.64	51.70	43.04
Alumina	40.81	42.87	39.67	39.01	42.36	43.24	43.79	40.97
Oxide of iron	1.03	.81	1.09	2.43	2.62	3.59	2.94	2.27
Lime	.62	1.30	1.43	1.09	.64	1.24	.62	.74
Magnesia	.55	.21	.11	.73	.36	.45	.67	.17
Loss on ignition	12.11	9.86	11.96	13.76	....	....	....	12.52
Alkalies	....	....	....	....	.83	.50	.70	....
Fusion point in cones	....	34	34	33	34	33 to 34	32 to 33	

"Nos. 5, 6 and 7 calcined samples; 1, 4, and 5 gray to black in color; 2, 3, and 6 white; 7 and 8 red.

ANALYSES BY DAVIDSON, RIES, AND GREAVES-WALKER.

"Above this semi-flint, the regular No. 1 flint occurs. It is light cream in color, very pure and breaks with a clean, conchoidal fracture. It is very evenly distributed through the vein, averaging about 8 feet. It is quite brittle, and hence bores and shoots easily.

"As the following analyses will show, it is probably one of the purest clays in the world. It will be noted that the chemical water content is generally above that of kaolinite. The high fusion point is also notable.

TABLE No. 2.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Silica	45.65	43.76	44.31	46.20	43.58	43.38	52.81
Alumina	39.96	40.21	39.50	39.35	40.86	40.35	42.08
Oxide of iron	.14	.53	.56	.10	.76	.85	3.26
Lime	.21	.88	.60	.15	.29	1.26	.42
Magnesia	.12	.06	Tr.	.09	.14	.23	.45
Alkalies	.18	....	....	.22	.24	....	.40
Loss on ignition	13.75	14.12	14.03	14.00	14.43	13.41	....
Fusion point in cones	35 to 36	35 to 36	35 to 36	....	....	....	34

No. 7 calcined sample.

ANALYSES BY DAVIDSON, RIES AND GREAVES-WALKER.

" 'Sandy flint' and 'high silica flint' is the name given to a flint clay which replaces the No. 1 flint on the outer edges of the lense-shaped deposits. The matrix is of the same composition as the No. 1, but is full of small crystals of pure quartz. The percentage of silica decreases on working away from the edge of the deposits, and entirely disappears about 100 feet in. For the amount of free silica present, this clay stands a remarkable heat test, and it is very valuable for purposes where a brick of high silica content is required. Analyses of 'sandy flint' follow:

TABLE No. 3.

	No. 1	No. 2	No. 3	No. 4	No. 5
Silica	57.68	50.90	58.34	58.14	50.87
Alumina	27.95	38.00	33.34	26.39	36.02
Oxide of iron	1.62	Tr.	1.02	1.26	.59
Lime	.51	.80	.72	.84	.53
Magnesia	.24	Tr.	.36	Tr.	.17
Loss on ignition	11.52	10.10	6.13	14.07	11.42
Fusion point in cones	33 to 34	34 to 35	34 to 35	34	

Analyses by Greaves-Walker.

"A most remarkable freak clay occurs above the No. 1 flint. This is known as 'aluminite' or 'high alumina flint.' It was fully described in a note in Vol. VII of the Transactions American Ceramic Society, so that it will not again be necessary to go into particulars here. This clay is not found generally throughout the Kentucky deposits, in fact, the only occurrence so far as is now known, is the one in this mine. It does not slake on exposure to the weather, and is extremely hard, breaking with a rock fracture. Analyses follow:

TABLE No. 4.

	No. 1	No. 2	No. 3	No. 4
Silica	39.56	34.76	39.01	37.21
Alumina	43.35	48.50	42.01	43.76
Oxide of iron	2.57	1.26	4.04	3.53
Lime	.56	.76	.68	.88
Magnesia	.50	.11	.45	.06
Loss on ignition	13.09	14.08	14.00	14.12
Fusion point in cones	36	36	34	

Analyses by Davidson, Ries and Greaves-Walker.

Above the flint clay he describes the No. 2 plastic clay and gives the following analyses:

TABLE No. 5.

	No. 1	No. 2
Silica	47.08	47.08
Alumina	36.12	39.86
Oxide of iron	2.08	.88
Lime } Magnesia }	.86	Tr. / Tr.
Loss on ignition	13.75	12.34
Fusion point in cones	33	34

Analyses by Greaves-Walker.

A remarkably pure plastic clay from the Blankenship mine was analyzed by Greaves-Walker with the results given in No. 2 of the last table.

The company is now getting its clay from the Qualls' mine, near the headwaters of Perry's branch, and from the Montgomery mine on the waters of Trough Camp

creek. The latter mine is about five miles from Olive Hill and is connected with the plant by a narrow gauge railroad.

At the Qualls' mine the clay is six feet thick on an average with about two feet of flint, and four feet of No. 2 plastic. The two clays are found in the same vein. In some places there are from one to one and a half feet of "semi-hard" clay which as the name signifies, is a grade between the flint and the plastic clays.

"Silica boulders" are found in the mine. These boulders contain more or less alumina and are refractory. When placed in the air for a time they slack into fine particles very similar to clay. They are found in all parts of the clay bed but more frequently they occur near the top of the clay. Impressions of calamites are found in the silica boulders. Near the top where they come in contact with the shale roof the color of the silica changes from dark to gray and white farther down. Small angular fragments of flint clay are occasionally found imbedded in the "silica boulders." The edges of the fragments are very sharp showing they have been carried only a short distance and deposited in the siliceous material by a very sluggish current.

The No. 2 plastic clay may be of a dark color due to the presence of organic matter. Impressions of leaves, reeds and other organic remains are very common in the plastic clay which may be mistaken for a black shale.

The flint clay is separated at the mine into No. 1 and No. 2. The No. 1 is of a light gray color, smooth to the touch, has an amorphous structure and breaks with a decided conchoidal fracture. On close examination it shows an oolitic structure very similar to the oolitic Chester limestone.

The No. 2 flint is less uniform in color than the No. 1, and frequently contains small grains of pyrite or marcasite. Otherwise it is similar to the No. 1 flint.

There is a thin vein of coal one to two inches thick on top of the fire clay with about eight feet of black shale roof above the coal. The shale is filled with leaf impressions.

The Montgomery mine was just being opened at the time of the writer's visit and but little could be observed.

The brick plant including the grinding rooms, dry floors, kilns and stock sheds covers more than an acre of ground. The clay is brought to the plant at the rate of about 60 to 75 car loads a day. The cars hold about one ton of clay each. The clay is used as it comes from the mine without washing or storing.

The various grades of clay, No. 1 and No. 2 flint, semi-hard and plastic, are all separated in the mines as they are loaded into the cars, and each car tagged with the kind of clay it contains and the name of the miner who loaded it.

Two large dry pans and one Griffin mill are used to grind the raw clay as it comes from the mine. Certain definite proportions of ground flint clay, calcine and plastic clay are mixed and re-ground in wet pans with sufficient amount of water to render the mixture a stiff mud.

There are two general features that govern the manufacture of high refractory brick. The first and most essential is to get a clay that will successfully stand up under a high degree of heat. The second is to get a clay that has a minimum amount of shrinkage. The No. 1 flint is regarded as the most refractory clay in the district, but it is practically void of plasticity. It contains a large percentage of water which gives it a high shrinkage ratio. The plastic clays, which are used as the bond, are likewise high shrinkage clays. To overcome the shrinkage calcine is mixed with the flint with sufficient plastic clay to make a substantial brick.

Calcine is made from the best grade of flint or "boulder clay" as it is frequently called. Where the calcine is to be used in the manufacture of fire brick less caution is used in selecting the raw clay than where the calcine is to be used in the manufacture of glass pots. The production for glass pot works will be found under the description of the Olive Hill Calcine Company.

When the flint clay is calcined it is placed in a kiln and subjected to a high heat until all the chemically combined water is driven off. This, of course, destroys what little amount of plasticity it originally had, but the object in calcining the clay is to eliminate the shrinkage. When the mixture is finely ground the bonding material shrinks around the fragments of the non-shrinkable calcine and a very durable brick is produced.

The color of the calcine, and likewise the brick, is controlled to some extent in the burning. If the drafts are left wide open and the product is burned in the presence of a great amount of oxygen the burned product will be cream colored to white. If the drafts are closed and very little oxygen is permitted to enter the kiln the material has a dark to nut-brown color. The latter color is desired by some lines of trade.

The formula of the various mixtures used by the different plants in the district are kept more or less a secret. There are three materials that enter into the manufacture of the high grade fire brick of this district. These are flint clay, calcine and plastic clay. The raw clays are all highly refractory and likewise have a high shrinkage ratio. A great amount of labor, time and expense have been spent in getting the proper mixtures of flint, calcine and plastic clays in producing a brick that will stand the wear and the heat to which they are subjected. This is done by combining definite proportions of flint, calcine and plastic clay. In blast furnaces there are four grades of fire brick used, viz.: Bottom, Hearth and Bosh. Inwall and Top. The Top bricks, where the ore enters, must be made to stand a great amount of abrasion as well as heat. To produce this kind of brick from a refractory clay with a high shrinkage ratio a great amount of calcine with sufficient plastic clay to bond it, is used and the material finely ground.

In the Inwall, which comes just below the Top, the abrasion is lessened and the brick is made with a corresponding smaller proportion of calcine and with an increased amount of flint clay. The proportion of flint clay increases in the Hearth and Bosh, and in the Bottom.

The finer the mixtures are ground the stronger the brick and the greater the amount of abrasion it will stand. This kind of brick has a clear ring when struck with a hammer, whereas a brick made of the coarsely-ground materials is brittle, stands very little abrasion, and has a dull lifeless ring. However, some lines of work demand the brick made of the coarsely-ground materials which take up the heat and absorb it more readily than the bricks of finer texture.

The plant has a daily capacity of 50,000 bricks. All of the high grade bricks are molded by hand. The plain bricks are first molded in hand-molds and placed on a cement dry-floor, which is heated from beneath by the exhaust from the engines. They are allowed to dry for a period of about six hours when they are taken up and repressed in a small, hand-power repress. They are then replaced on the dry floor and thoroughly dried when they are placed in the kiln. The bricks rarely check in drying.

The repress makes the bricks more compact, smoothes the faces and corners and imprints any desired name or design on the face of the brick.

One man will mold 4,600 standard-size bricks in a day of 5 to 6 hours.

All "shaped" bricks and large blocks are made of very stiff mud and not repressed. It requires more care and time to make the shaped bricks than those that are to be repressed. The shaped bricks are dried in the same manner as the others. When the air-drying is about half completed the corners and faces of the shaped bricks are dampened and smoothed with a wet trowel. This to some extent takes the place of repressing.

In addition to the hand-molded bricks the company has two Chambers soft-mud brick machines of 15,000 each, daily capacity. These can be regulated to make different sized bricks. The cheaper grades of brick are machine-molded.

An extra high refractory brick is made by this company from magnesite which comes from Austria. It is roasted or calcined in Europe to drive off all the water and render it as light as possible before shipping. Bricks* made of magnesite are very much used for lining electric furnaces, cement kilns, copper and basic steel furnaces. Magnesite bricks are more resistent to the corrosive action of basic slags and molten metals than bricks made of silicate of alumina.

Magnesite is a carbonate of magnesium (Mg CO3) and contains 52.4 per cent of carbon dioxide and 47.6 per cent of magnesia. It is found associated with serpentine† rocks from which it is supposed to be derived.

*F. L. Hess, Bull. 355, U. S. Geol. Survey, page 11.
†Ibid.

The magnesite as it comes from the roaster is in small irregular fragments and has a slightly reddish tinge. It is finely ground and mixed with enough water to make a stiff mud. Magnesite after it is calcined has, when finely ground and mixed with water, the peculiar property of becoming plastic. The bricks are molded by hand. A great amount of care is used in drying. They are dried on the steam-heated, cement, dry-floor for one day, then stacked in a large pile in the same dry room where they remain for another day. They are then taken into a cooler room where they are ricked up in large stacks and allowed to remain for four or five days longer. From here they are taken to the kilns.

The Olive Hill Fire Brick Company has 24 kilns of 70,000 to 80,000 each, capacity. Four kilns are used for burning calcine and 20 for burning bricks. The type of kiln used is the round, down-draft, twin kiln. Coal is used as the fuel. It requires about 7 days to burn a kiln of bricks. About 4 days are required to get a kiln to a good red heat. The temperature is gradually raised from red to a white heat where it is held for about 36 hours. In making bricks of a highly refractory clay like that found in the Olive Hill district the trouble is more likely to be in under burning the ware than overburning it.

Fire bricks from this plant are shipped to the Pittsburg iron and coke district, and to the Michigan and the Birmingham iron districts. A large amount of the brick is made in special molds for various purposes. Railroad locomotives require a specially prepared brick to stand the rough wear and the heat to which they are subjected. The Olive Hill fire brick has been found to give excellent service for this class of work.

HARBISON-WALKER REFRACTORIES COMPANY.—In 1901 the Harbison-Walker Refractories Company of Pittsburg, Pennsylvania, established a fire brick plant in Olive Hill. The plant is located on the west side of Henderson branch in the western part of Olive Hill.

Garvin (Mud Lick) Mine.—The mine from which the clay is obtained is located on the south side of Trough Camp branch, three miles northwest of Olive Hill. The clay is conveyed to the plant over a narrow gauge rail-

road, in small cars drawn by an engine. Twenty to thirty cars of clay are drawn at a time.

The ridge between Henderson's branch and Trough Camp rises to an elevation, barometic reading, of 1025 feet above sea level. The elevation of the mouth of Garvin mine is 930 feet above sea level.

The dividing ridge between the above mentioned streams is penetrated by a tunnel through which the railroad is built. The tunnel was built through the hill on the fire clay which was used at the plant.

There are two divisions of the Garvin mine, one on the east side and the other on the west side of a little branch which flows north into Trough Camp branch.

The clay is first worked around the edges of the hills by open cutting or turning the overburden until the latter becomes too thick to be profitably worked. Tunnels are then driven into the hill and rooms opened on either side similiar to a coal mine.

Holes are bored into the solid bed of clay by means of hand augers or "clay drills," and the clay blasted out with black powder. It requires about five minutes to bore a 4-foot hole in the clay.

Garvin mine has been one of the best clay producers in the district. It was opened in 1900 and has been worked constantly since. The west entry has been driven 1900 feet into the hill and the clay is from 4 to 10 feet thick exclusive of the bottom "pink eye." The following section which is an average one was measured in the mine:

	Feet	Inches.
Sandstone, fine grained	....	
Black "Huckleberry shale"	10	
Coal ..	....	2
Plastic clay with leaf impressions	2	
"Boulder-flint" clay with leaf impressions	3	
"Semi-hard" clay	3	
"Pink eye" calcareous clay	3	
Limestone.		

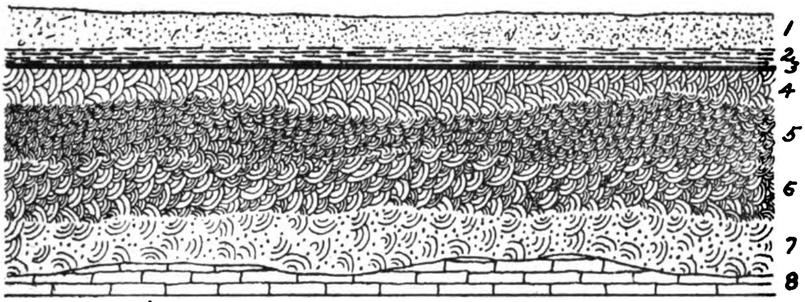


Fig. 2.

Section at Garvin Mine, Olive Hill, Ky.

1. **Fine grained Sandstone.**
2. **Black Shale.**
3. **Coal.**
4. **Plastic Clay with leaf impressions.**
5. **Flint Clay with leaf impressions.**
6. **Semi-hard Clay.**
7. **"Pink Eye" Clay.**
8. **Limestone.**

The black shale which forms the roof of most of the clay mines of the district is known locally as "Huckleberry shale." The little coal seam at the base of the shale is known as "Huckleberry coal." The latter is usually one to three inches thick in the vicinity of Olive Hill and thickens to the east. It is very persistent throughout the Olive Hill fire clay belt.

The plastic clay at the top of the deposit is usually dark colored, the color being due to the presence of vegetable matter. The flint and semi-hard varieties are of a rich gray color, and are greasy to the touch. A small amount of iron is present in the plastic clay, whereas the flint and semi-hard clays burn to a light cream or white.

An extra pure deposit of flint clay was encountered in the southeast part of the mine and is known as "Bessemer flint." It is said to be the purest form of clay found in the district, but no analysis of it could be obtained. It is doubtless the equivalent of the "aluminite" of Greaves-Walker.

Lense-shaped bodies of a fine-grained sandstone are found to a greater or less extent in these mines. They

are known as "silica boulders" or "nigger heads." They usually occur in the top of the clay although one instance was found, at Hayward, where they came in from the bottom. On close examination they are found to contain minute grains of sharp sand cemented with fire clay. They are remarkably free of iron and other impurities.

As may be expected from their composition *they are very refractory, and are used by the Harbison-Walker Company in the manufacture of a fire brick which is known as "free-bond silica brick." The silica is ground and faithfully mixed with sufficient plastic clay to bond the sand particles, and burned. A very satisfactory brick is thus produced which is equal if not superior to the famous Dinas brick of England. They have given good service where the abrasion is not too great.

The writer was unable to get the formula of the mixes used in the manufacture of the "free-bond silica bricks" so that comparison with the Dinas fire-brick and the German and the French silica bricks is impossible. It may be interesting to note here the nature of the foreign silica bricks.

The English Dinas fire brick are made of the purest form of quartz faithfully mixed with alumina, lime and magnesia. The alumina usually contain a small amount of oxide of iron. They are much used at Swansea in the construction of copper furnaces. The average composition of these bricks consists of about 96 per cent of silica and 4 per cent of fluxes, 2 per cent of which is lime, 1.2 per cent of alumina and the remainder iron oxide and magnesia.

A siliceous fire brick is made in Austria, according to C. T. Davis in his book on the Manufacture of Bricks, Tiles, Terra Cotta, etc. It is made of 16 parts of quartz, to one of plastic clay. The quartz is first placed in a roasting oven and at the end of twelve hours it is raised to red heat, taken out and thrown into water. The quartz is then crushed and mixed with the clay which is ground to pass through a 600 mesh-screen.

The bricks are then molded and subjected to a heavy pressure before they are removed from the molds. They are then removed and dried for seven days when they are

*See analyses, on another page of this report.

ready to be set in the kiln. It requires seventy-two hours to raise them to a strong white heat. The fires are then withdrawn and the entire kiln ceiled air tight and allowed to remain in this condition for thirty-six hours. The charging place is then gradually opened and the bricks are permitted to cool slowly for about seventy hours more when they may be removed.

Some interesting core-holes were made on the Harbison-Walker Company's land in the vicinity of Olive Hill. The following records were furnished the writer by Mr. O. S. Boggs, Superintendent of the mines.

(1) Core-Drill Hole at Head of Perry's Branch.

	Feet
Surface	10
Shale	55
Sandstone	3
Mississippian limestone.	

(2) Core-Drill Hole on Henderson's Fork of Perry's Branch.

	Feet	Inches.
Surface	10	
Sandy shale	20	
Black slate (shale)	25	
Flint clay	11	8
Semi-hard clay	5	
"Pink eye" clay	3	4

(3) Core-Drill Hole on Trough Camp Branch.

	Feet	Inches.
Surface	8	
Shale	27	
Sandstone	4	
Slate (shale)	28	
"Huckleberry coal"	....	2
Top "pink eye" clay which is a pinkish clay that burns white. Not present throughout the district	3	10
Slate (shale)	18	
Hard flint clay	4	
Semi-hard clay	3	
Lower "pink eye" clay	2	
Limestone.		

(4) Core-Drill Hole on Trough Camp Branch.

	Feet
Surface	12
Slate (shale)	28
"Huckleberry shale"	4
Shale	36
Sandstone	3
Bottom "pink eye"	11
Limestone.	

The records are reproduced as they were given from Mr. Boggs' notes made when the holes were bored, except where he has given "slate" the writer has used the word "shale" in brackets "[ ]".

The drill holes were made for the purpose of determining the presence, and if present, the thickness and character of the fire clay.

It will be noted in studying the records that no clay of any kind was found in hole No. 1. The Huckleberry shale and the thin coal that comes between this shale and the fire clay were also absent.

In hole No. 2 the coal was not found, but a thick deposit of flint, semi-hard and "pink-eye" clays was penetrated.

In hole No. 3 an 18-foot of shale was found between the flint clay and the little coal seam. Such a thickness of shale at this geologic horizon is unusual. But for the presence of the coal seam above the "top pink eye" clay the writer would be inclined to call the 18-foot bed of shale the "Huckleberry shale," but the location of the coal precludes this.

In core-hole No. 4 the coal and the fire clay are both wanting with only the bottom "pink eye" present.

While the exact relative locations of these core-holes are not given on the map it is evident that the fire clay deposits are more or less irregular or basin-shaped in extent. It may also be interesting to note that no plastic clay was found above the flint clay in any of the holes. Where the flint clay was encountered it was always underlaid by a bed of semi-hard clay and underneath this was a deposit of "pink eye", which rests directly on the limestone.

The Harbison-Walker Company has two dry pans nine feet in diameter for grinding the clay. The clay is mixed with water and made into a stiff mud ready for molding in three large wet pans of the same dimensions as the dry pans. All of the high-grade bricks are hand-molded and the standard sizes are repressed after they are partially dried. The cheaper bricks are made in a steam brick machine of 30,000 daily capacity.

The bricks after molding are placed on a cement floor to dry. The floor is heated from beneath by artificial heat, and kept at a fairly even temperature. After drying for 2 to 4 hours, depending on the size of the bricks, the bricks are turned and allowed to dry on the other side. When a part of the moisture has been expelled some of the bricks are repressed, and the serrated edges and the rough surfaces of the irregular designs are smoothed with a wet trowel.

When thoroughly dried on the hot cement floor the bricks are hauled in wheelbarrows and stacked in the kilns.

It requires about 7 days to burn a kiln of brick. Coal is used as fuel.

The company has 12 kilns for burning bricks and two for burning calcine. The kilns are all round, down-draft twin kilns; that is they have one stack which is connected with each kiln by means of underground tunnels. The two kilns are filled simultaneously with green bricks, and, after burning are emptied in the same way.

The company produces about 55,000 standard-sized bricks a day. The mixtures of flint, semi-hard, plastic clays and calcine used at this plant depend on the use to which the product is to be applied. Each company in this field engaged in the manufacture of refractory brick has worked out its own formula of mixtures best adapted for its trade. Analyses of the various clays used are furnished their customers when desired and frequently orders are given for a certain amount of bricks to contain specified proportions of calcine, flint and plastics. It is stated by some of the brick makers that a brick which gives the best service in a blast furnace in the Pittsburg district may not meet the requirements of an iron furnace in the Birmingham or the Mesabi districts.

OLIVE HILL CALCINE CO. In 1910 the Olive Hill Calcine Company established a two-kiln calcine plant at Olive Hill on Henderson's branch, opposite the Harbison-Walker brick plant. The two kilns have a combined capacity of 600 tons of calcine. They are round, down-draft, twin-kilns and must, therefore, be filled, burned and emptied as one kiln.

The best grade of flint and semi-hard clay is used in burning calcine. The plastic, and the harder clays that do not come up to the standard for glass pot manufacture, are sold to fire brick companies in Cincinnati, Louisville, Rome (Georgia) and other places.

The calcine of this company is sold exclusively to glass-pot factories for the manufacture of glass pots. Formerly all the glass pots made in this country were made of German clays, but it was found by experiment that the Olive Hill fire clay is superior in refractoriness to the German clays. Calcine for the manufacture of glass pots must be highly refractory and of a uniform color. A pure white calcine is the most desirable. The manufacturers will accept it if the color is a rich cream, but reject it when the color begins to assume a bluish cast. The best boulder flint clays will calcine to a white; the semi-hard, if burned with the drafts wide open, assume a rich cream color. The plastic clays all burn dark and are, therefore, culled and shipped to fire brick companies for the manufacture of fire bricks.

On account of the restrictions placed on the color of the calcine that is to be used for glass-pot manufacture great care must be used in burning the clay. There is no accurate method used at this plant for determining the heat in the kiln at any stage of the burning, but a constant watch is kept on the color of the heat through an apertune in the kiln-wall. Red is the first color observed, then at about 2,250 degrees F.—estimated by the foreman—the clay assumes a cream color. At about 2,500 degrees F. the clay changes to white; at a still higher temperature it becomes blue, and finally, if the heat is continued, to a dark splotchy iron color. The last color is supposed to take place at about 2,750 degrees F.

The objects in calcining the clay is to drive off all the chemically combined water, and to destroy the shrinkage. As stated previously it is also essential to get a white or a cream color, but frequently the kilns do not draw evenly, and drafts will develop in certain parts of the kilns where the clay is burned harder than in other parts. The upper part of the kiln is burned harder than the lower part.

The unequal drafts in a kiln are largely the result of the way the clay is placed in the kiln. No finely pulverized clay is allowed in the kilns as very much of this would choke the draft entirely. Boulders of various sizes, and the larger the better, are piled one on the other in such a manner as to give an opportunity for the heat to freely circulate through the clay. If the temperature is raised too rapidly the clay crumbles to fine particles and thus chokes the draft.

If the clay is overburned it is necessary to hand pick the calcine that is to be used for glass-pot manufacture. The dark colored materials are sold to fire brick plants.

The Olive Hill Calcine Company has two mines which are located up the right fork of Henderson's branch about one mile from the plant. The clay is conveyed from the mine to the plant over a narrow guage railroad. A small engine draws eight to fifteen cars of clay. The following section was made at the mouth of and inside of one of the mines.

	Feet	Inches.
Sandstone and shale.		
Hard shale with leaf impressions	20	
Coal	....	2
Flint clay, No. 2 with leaf impressions and occasionally has some iron	1	6
Plastic clay with leaf impressions	1	6
Flint or "glass pot" clay	2	6
Semi-hard clay	2	6
Limestone.		

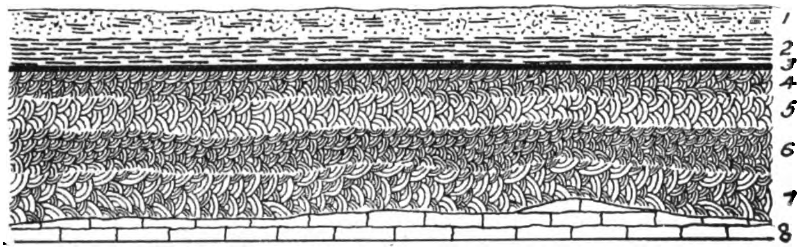


Fig. 3.

Section at Olive Hill Calcine Company's Mill, Olive Hill Ky.

1. **Shaly Sandstone.**
2. **Dark Shale with leaf impressions.**
3. **Coal.**
4. **Flint Clay with leaf impressions.**
5. **Plastic Clay with leaf impressions.**
6. **Flint Clay, best grade.**
7. **Semi-hard Clay.**
8. **Limestone.**

The above section is about an average thickness of the clay in the mine. In some places, however, silica boulders or "rolls" come in from the top and cut out the clay. These silica boulders are here called "nigger heads." Slickensided clay is frequently found near the silica boulders. At one place there is a fault of 36 inches displacement of the flint clay.

The silica boulders found in this mine are composed of a gray, fine-grained sand cemented with silicate of alumina; when exposed to the elements for a few days they completely decompose. The silica grains have sharp angles and throughout the mass may be seen angular fragments of flint clay which could not have been carried a great distance from their original beds.

The roof throughout the mine is a firm shale and generally level. The inequalities in the thickness of the clay more frequently come in at the bottom; however, the silica boulders which come in at the top may represent channels eroded in the clay and subsequently filled with silica mixed with various sized particles of clay. The angular fragments of flint clay in the sand matrix indicate that the silica boulders were formed after the flint clay had crystallized in the condition it is found in the flint beds and in the sand matrix.

SMITH RUN.

Some of the finest samples of flint clay found in the district were collected on Smith Run 3 to 4 miles west of Olive hill. A number of openings have been made on the fire clay on this branch, and also on Sugar Camp branch.

At an opening made on the Olive Hill Clay Products Company's land on the west side of Smith Run, the following section of the pit was made:

	Feet	Inches.
Covered.		
Plastic clay	1	6
Best grade of No. 1 flint	4	
Said to be plastic clay below.		

A car load of flint clay was shipped from this place for experimental purposes. The flint clay from this opening is light gray to white, and free of iron stains and carbonaceous matter.

Through the courtesy of the Olive Hill Clay Products Company, the following analyses of the raw clay, calcine, and of the brick made of this clay were furnished the writer. The analyses and fusion tests were made by the Didier-March Company, Perth Amboy, New Jersey:

Analyses of Clay and Calcine.

	Raw Clay. Per cent.	Calcine Per cent.
Silica	44.0	51.4
Alumina	42.5	46.4
Iron oxide	1.0	1.25
Lime	0.5	0.57
Fusion point: Cones 34-35.		

Analysis of Brick.

	Per cent.
Silica	54.6
Alumina	42.9
Iron oxide	1.2
Lime	0.5
Fusion point: Cone 35.	

The fusion point of cone 35 is the equivalent of 3,326 degrees Fahrenheit or 1,830 degrees Centigrade. This may be ranked as one of the most refractory clays known.

On the Frank River's land near the head waters of Sugar Camp branch and within a few hundred yards of the Lewis County line is a deposit of flint clay that greatly resembles bauxite. It is highly oolitic and may readily be taken for a piece of oolitic limestone. It is evidently a reworked deposit as it contains angular fragments of flint of a greenish tinge imbedded in the clay matrix. It is exceedingly close grained and heavy, and breaks with a conchoidal fracture. Fragments of this clay have been plowed up in the field and exposed for years without disintegrating. This is very unusual as most of the flint clay in the district, on exposure to the elements for a few weeks, breaks up completely into finely divided particles.

The water shed between the waters of Tygart creek and those of Kinniconick forms the boundary between Carter and Lewis counties. The fire clay occurs at about the horizon of the low divides, and on some of the high north-south ridges extends as much as a mile into Lewis county.

There is a rapid eastward dip of the clay in this locality. The elevation of the clay at the headwaters of Sugar Camp branch is 1,050 feet above sea level or 130 feet higher than the mouth of the Olive Hill Calcine Company's mine on Henderson's branch. The distance between the two places is approximately four miles giving an eastward dip of 32 feet to the mile.

HAYWARD. In 1900, the Ashland Fire Brick Company established a fire brick plant on the main line of the Chesapeake and Ohio Railroad, at Hayward, one mile east of Soldier. The plant has a daily output of 10,000 to 12,000 bricks. The bricks are burned in rectangular down-draft kilns. There are five kilns for burning brick and two for burning calcine.

The plant and the mine of this company are favorably located with respect to each other. The plant is located within 200 yards of the Chesapeake and Ohio Railroad and the mine where the clay is obtained is in the hill just south of the plant. The mouth of the mine is about 100 feet above the plant. The clay is drawn out of the mine in small cars drawn by mules. Near the mouth of the mine is a small house underneath which is a large wooden drum which contains two coils of wire rope long enough to reach to the brick plant. There is a double

track of light steel rails from the drum-house to the plant and the rope is so arranged that a loaded car going down hill to the plant draws an empty car up the other track to the mine.

About one-fourth of the clay taken from this mine is used at the Hayward plant and the remaining three-fourths are loaded in cars and shipped to the Ashland plants. The clay for the Ashland plants is loaded into cars from a tipple built at the end of a separate incline operated with a drum and wire cable similar to the one above described. The following is a section of the Hayward mine at the entrance:

	Feet	Inches.
Sandstone	5	
"Whim rock"	....	14
Coal	....	1-2
Flint clay	2	
Semi-hard clay	3	
"Pink eye"	....	8-18
Limestone.		

Section of Hayward mine near center of hill:

	Feet	Inches.
Sandstone	5	
Shale	4-6	
"Draw slate"	1-1½	
Bastard flint clay	....	4-6
Semi-hard clay	3-7	
Flint clay	2-4	
"Pink eye clay."		
Lime rock.		

A siliceous sandstone or silica rock, so prevalent in the vicinity of Olive Hill, was also found in the Hayward mine. Here, however, it always occurs at the bottom in the shape of a lense, instead of on top of the clay.

In the southwest part of the mine, about 175 feet from the crop of the hill, a black shale interstratified with sand was encountered. The shale lies on the same level as the clay, but the bottom edges of the shale underlie the clay as shown in Figure 4.

The bottom of the clay in this mine reveals the same uneven, wavy nature as observed in the mines at Olive

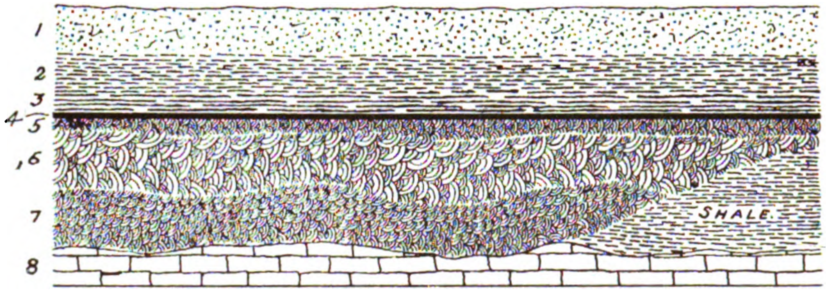


Fig. 4.

Section at Ashland Fire Brick Company's Mine, at Hayward, Ky., one mile east of Soldier, Ky.

1. **Sandstone.**
2. **Shale.**
3. **Draw Slate.**
4. **Coal.**
5. **Bastard Flint Clay.**
6. **Semi-hard Clay.**
7. **Flint Clay.**
8. **Limestone.**

Hill. The top of the clay is practically level. The thickening and thinning of the clay take place at the bottom.

When the "whim rock," the overlying shale and the siliceous sandstone are exposed to the surface for a few weeks, they disintegrate as the flint clay does.

More or less iron is found in the "whim rock" and in the roof slate.

CLINTON MINE.—The Clinton mine is located about ½ mile northwest of Soldier. It is owned by the Ashland Fire Brick Company, of Ashland, Kentucky. The clay is reported to be 5½ feet thick, with 18 inches of flint and the remainder semi-hard. The mine was operated for about ten years and the product shipped to Ashland. The clay is reported to have been of good quality. At the present time the Hayward mine supplies sufficient clay for the Ashland plants and is more accessible to the railroad than the Clinton mine.

VINCENT MINE.—About one-half mile north of Soldier, on the property of L. S. Vincent, an opening was made into the fire clay for a distance of 25 feet. The clay is 7 to 8 feet thick with about two feet of flint, two to two

and a half feet of semi-hard and the remainder of plastic. The hill where the clay was opened has a very gentle slope and the roof was not fully developed, but showed indications of a good shale roof. The ridge in which the clay was opened extends unbroken for nearly a mile to the north.

Three openings have been made on the fire clay on Mr. Vincent's land in the hill just south of Soldier. The openings were driven about 100 feet in the hill under a good shale. The flint clay here is 2 to 3 feet thick with about 2 feet of semi-hard clay below and the same thickness of plastic above. Some flint clay from these openings was shipped to the Massillon Stone and Fire Brick Company, of Massillon, Ohio; to the Ashland Fire Brick Company, of Ashland, Kentucky; to A. J. Hoblitzell, of Birmingham, Alabama, and to the Louisville Fire Brick Works, of Louisville, Kentucky.

WHITT AND KING OPENINGS.—A large tract of clay land lying to the south of Soldier, now belonging to Messrs. Whitt and King, has been partially developed. An opening was made on this property at a point one-fourth of a mile south of Soldier in 1907 with the intention of erecting a fire brick plant. A spur was graded from the mine to the main line of the Chesapeake and Ohio Railroad, and preparations made for erecting the plant, but the death of the president of the company put an end to the undertaking. The property was then owned by the Carter County Fire Brick Company. It has since passed to the present owners, Messrs. Whitt and King.

Another opening on the same property was made on the clay for a distance of 95 feet into the hill. Seven feet of semi-hard clay was found. On the southwest side of same hill the clay was found to be 7 feet thick and of good quality.

POWERS CLAY MINE.—About 4 feet of flint and 2 feet of semi-hard clay of good quality are reported to have been operated on William Powers' land 2½ miles north of Soldier. The opening was made in 1906. The distance from the railroad and the low price of the clay have prohibited its being worked.

EDEN CLAY MINE.—An opening has been made on the fire clay on George Eden's land 1½ miles north of Soldier. The flint and semi-hard clays were found to be 6 feet

thick, with a good shale roof and the "pink eye" clay at the bottom. The mine was opened about 1904 and some clay shipped to Pittsburg. The clay is said to have been rejected on account of not being carefully selected.

PATTON CLAY MINE.—Mr. J. D. Patton operated a clay mine three-fourths of a mile north and west of Soldier from 1907 to 1912. A spur from the Chesapeake and Ohio Railroad connects the mine with the main line of the railroad. The clay is from 6 to 11 feet thick and has a good shale roof and "pink eye" clay bottom. The clay in this mine consists of about 90 per cent semi-hard and 10 per cent flint. The latter occurs near the center of the vein. That above the flint has a bluish tint and is more plastic than the clay below the flint which is white. The bottom of the clay is uneven and lies in rolls or waves.

The same persistent coal seam which occurs on top of the clay is found in this mine. It varies in thickness from 2 to 4 inches. The shale above the coal is about 10 feet thick.

The clay from this mine was shipped to Woods-Lloyd Company, of Pittsburg; to the Louisville Fire Brick Works, of Louisville; and to the Ohio Valley Clay Pot Company, of Steubenville, Ohio.

HALDEMAN.—In 1903 the Kentucky Fire Brick Company of Portsmouth, Ohio, established a fire brick plant at Haldeman, which is located a few hundred yards west of Triplett tunnel in Rowan County.

The plant is located about 250 yards up a little draw from Haldeman station and is connected by a spur with the Chesapeake and Ohio Railroad. The mouth of the mine is right at the plant and only 30 feet above the grinding room. The clay is brought out of the mine in cars drawn by mules and dumped over the tipple at the grinding shed where the clay is mixed and dried in the same manner as it is done at the Olive Hill plants. The kilns are built on two sides of the drying room. After burning, the bricks are stored in the stock sheds from whence they are loaded directly into the cars for shipment. The plant has 14 kilns with a daily output of 40,000 to 50,000 bricks.

The products of the plant are shipped to Birmingham, Pittsburg, Cleveland and other places to the north and the west.

The mine from which the clay is obtained is located on the south side of the plant. The entry was first driven 240 feet due south, then turned in a southeastern direction and followed under the crest of the ridge for a distance of 1,800 feet with comparatively few side rooms. The mine is still in a state of development.

There is no whim rock and only a small amount of silica rock in this mine. At no place has the silica cut out the clay. The clay has an excellent shale roof 15 feet thick with 5 feet of sandstone above the shale. The mine is comparatively free of water.

The clay will average 6 feet in thickness throughout the mine and varies very little from that amount. The run of the mine, according to Mr. H. K. Leighow, the General Manager, will average 40 per cent of flint, 40 per cent of semi-hard and 20 per cent of plastics.

The following is a section made at the mine:

	Feet	Inches.
Sandstone	5	
Shale	15	
Coal	....	4
Thin layers of shale in some places.		
Plastic clay	....	12-20
Flint clay	....	26-30
Semi-hard clay	....	26-30
"Pink eye clay."		

The "pink eye clay" is known to be 6 feet thick, but has never been penetrated. The limestone was not seen west of Triplett tunnel, but is reported to be very thin in places.

The hill at the plant rises 150 feet above the level of the clay and is one of the highest in this region. At a point about 90 feet above the clay is a ledge of comparatively pure sandstone which is mined by the company, ground and mixed with the plastic clay and burned into a silica brick. It is reported to give good service in coke ovens and other places where it has been used. Here and at the Harbison-Walker plant at Olive Hill are the only two places in the district where the silica bricks are made.

BRINEGAR CLAY MINE.—At the Brinegar clay mine, 3 miles southeast of Haldeman, an opening was driven on the clay for a distance of 1,000 feet in the hill. The clay was about 6 feet thick with 3 feet of flint and the same thickness of semi-hard. The mine was operated for about eight years and was finally abandoned on account of the low price of clay and high freight rates. The flint clay only was shipped. It was hauled to the railroad at Enterprise over a tram road, and shipped to Portsmouth, Ohio.

The heavy bedded conglomerate sandstone is absent in the region about Soldier and Haldeman, but is more than 75 feet thick at Limestone. It thins to the west and on the east side of Triplett tunnel, it is either very thin or entirely gone. No limestone was seen around Haldeman on the west side of the tunnel. It was found near the tops of the hills farther west in the vicinty of Morehead.

ELLIOTTVILLE.—Extensive deposits of fire clay occur in the immediate vicinity of Elliottville on the headwaters of Christy creek and also on the east side of the divide on the headwaters of Tygart, Big Sinking, Little and Big Caney Creeks. The clay of this territory is still undeveloped due to a lack of transportation facilities.

The territory to the north and east of Elliottville has been thoroughly tested by core drill holes and a large percentage of the best clay land bought up by the Harbison-Walker Refractories Company. The results of their work show that the clay deposits are extensive and the quality as good as the best clay found in the vicinity of Olive Hill. Other companies have also acquired considerable clay land in this region. Most of this territory will doubtless remain undeveloped until the clay nearer the railroad has been exhausted. It is only a question of time, however, when this territory will be one of the largest clay producing areas of the Olive Hill district.

The territory east of the north-south divide, from Soldier to Elliottville can be easily reached by a tram road from Enterprise up the South Fork of Tygart creek. The clay from the west side of the divide could be taken out over a tram road up Christy creek from Rodman. In either instance it would require eight to ten miles of tram

road to connect the center of the clay field with the Chesapeake and Ohio Railroad.

In the Elliottville region the Mississippian limestone is generally present. It is about thirty feet thick on the headwaters of Christy Creek. It is also present on the headwaters of Tygart, Big Sinking, Big and Little Caney and Laurel creeks. It is sixty feet thick on Main Caney creek, three miles south of Elliottville.

In the immediate vicinity of Elliottville the Conglomerate is either entirely absent or in very irregular areas. It thickens to the east and south. It is 90 feet thick at the head of Laurel. Three miles northwest of Newfoundland, in Elliott County on Big Caney, it is 180 feet thick with the limestone in the bed of the creek.

The fire clay outcrops in the road in the town of Elliottville a short distance below the postoffice at an elevation above sea level of 1,050 feet. A core drill hole put down by the Harbison-Walker Company on G. L. Maccabee's land about 200 yards east of the outcrop in the road is reported to have shown the following:

	Feet.
Plastic clay	7
No. 1 flint clay	7
Semi-hard clay	2

The Mississippian limestone outcrops in the road just below the fire clay.

A deposit of flint fire clay outcrops on Jesse Bryant's place near the head of Andy White branch. Here the clay is 30 feet above the top of limestone. A ledge of coarse-grained sandstone forms the interval between the limestone and the fire clay. The clay is of a light gray color and apparently free of impurities. The following is a section of the deposit:

	Feet.
No. 1 flint	2½
Semi-hard	2
Plastic—bottom not seen.	

About 300 yards farther down the same branch the fire clay rests directly on the Mississippian limestone.

At an old clay opening on Walker branch two miles below Elliottville the flint clay is seven feet thick. The

clay here contains a large amount of free silica and is of a greenish color due to the presence of iron. The clay is very hard, and on exposure to the elements, does not disintegrate readily. The elevation of the clay on Walker branch is 30 feet higher than it is at Elliottville, giving a southeastward dip of 15 feet to the mile.

The fire clay has been opened on the following places on the headwaters of Christy creek: F. M. Weaver's, A. J. White's, E. S. Hogg's, John Scague's, Jerry Fletcher's, George Bruce's, J. D. Walker's, Emery Bates.'

In the Elliottville territory the fire clay at the top of the limestone is overlain by a thin vein of coal with ten to twelve feet of shale above the coal. Above the shale comes five to ten feet of thinly bedded sandstone with layers of shale between. The No. 4 plastic clay which comes just above the coal is found in some of the openings.

CRANEY CREEK.—The fire clay deposits diminsh in extent and thickness on going southward from Elliottville. The quality of the clay is likewise poorer than to the northeast. The Conglomerate sandstone is very prominent in all of the country from Elliottville to Licking river. A few deposits of fire clay were observed on the headwaters of Craney. Flint clay fragments that have withstood the weathering agents were seen in the road on main Craney about three miles south of Elliottville. Elevation of the clay is 1,040 feet above sea level.

About one mile farther south on the same stream the fire clay horizon is plainly marked on the sides of the hill by a bench at the top of the Mississippian limestone. The clay, where exposed at the surface, is of fair quality, but it has never been developed.

WAGGONER BRANCH.—There is an exposure of the fire clay at an elevation of 1,055 feet above sea level at the head of Hammon's branch, a small tributary to Waggoner branch. The Mississippian limestone here is fifty feet thick with a ten foot bed of lithographic stone between this and the Waverly. At the base of the Conglomerate the fire clay is about ten feet thick; the upper part of the exposure is a hard, bluish flint clay. The elevation of the clay, barometric reading, is 1,055 feet above sea level.

The crest of the ridge between Waggoner branch and Dry Fork, barometric reading, is 1,230 feet above sea level. The Conglomerate here is 80 feet thick. The bed of Waggoner's branch near its mouth is 860 feet above sea level.

MOREHEAD.—The Waverly sandstones and shales form the surface of Rowan County to the north and west of Morehead. East of Triplett creek the Mississippian limestone catches under the tops of the hills and dips to the east and southeast. Triplett creek from the mouth of Dry Fork to Triplett practically marks the northwestern boundary of the Mississippian limestone. The high hill just east of the depot at Morehead shows about 530 feet of Waverly and large blocks of Mississippian limestone.

Near the base of the hills just north and northwest of Morehead is a bed of Waverly shales that are well adapted to the manufacture of paving brick, sewer pipe and fancy English face bricks. The shale deposit is 50 to 75 feet thick and could be mined by steam shovel or by plow and scraper method. A number of locations could be found near the main line of the Chesapeake and Ohio Railroad where a plant could be built with the shale near at hand. Samples of shale from Morton Laim's land, just outside the town of Morehead, were sent to the Olive Hill Fire Brick Company's plant at Olive Hill and made into brick. The bricks made of this shale are reported to have burned to a deep red color with a uniform spotted surface appearance due to the presence of iron in the form of pyrite.

The same shale horizon is continuous from Mr. Laim's house through Mr. F. C. Nickell's land to the Chesapeake and Ohio Railroad at Brady switch, one mile west of Morehead.

The most extreme southwestern point where the fire clay is known to have been worked is on Mr. Sam Bradley's land, three miles south of Morehead near the head of Morgan branch. The flint fire clay occurs forty feet below the crest of a high hill just west of the Morehead and North Fork railroad. The elevation of the top of the hill is 1,280 feet above sea level. Elevation of the clay horizon is 1,240 feet. The base of the Mississippian

limestone at this place is 1,100 feet above sea level. The clay occurs up in the Conglomerate, perhaps 40 feet or more above the top of the Mississippian limestone.

About sixteen years ago the fire clay was mined at this place by Mr. William Cooper and several car loads shipped. The clay was hauled by wagons to Brady's switch, on the Chesapeake and Ohio Railroad, one mile west of Morehead. The clay is reported to be five feet thick. The work was abandoned on account of the expense of hauling.

YOCUM CREEK.—Yocum creek is a stream about three miles long which enters North Fork of Licking River from the south, opposite Paragon. It has cut its bed through the heavy bedded Conglomerate sandstone and the Mississippian limestone and exposed the upper strata of the Waverly for a distance of about two miles up the stream.

The flint fire clay has been opened at two or three places on this stream. On Hog Camp branch, about three-fourths of a mile from the head of Yocum, a good quality of fire clay was opened in 1911. The thickness was reported to be nine feet.

A short distance above the mouth of Hog Camp branch on main Yocum, the fire clay is wanting. The following is a section of the contact between the Conglomerate and the Mississippian limestone at this place:

	Feet	Inches.
Conglomerate.		
Thin band of blue limestone	....	4
Calcareous black shale	5	
Mississippian limestone.		

NORTH FORK OF LICKING RIVER.—In the district along North Fork between the mouth of Yocum and the mouth of Devil's Fork, the fire clay is either wanting or is of such a poor quality that it is worthless. The country is very rugged with high precipitous cliffs bordering the streams. The streams all show very rapid down-cutting with practically no valleys. A large per cent of the work of the streams of this region has been employed in cutting through the Conglomerate sandstone which is from 125 to 175 feet in thickness. The Mississippian limestone

is from 25 to 40 feet thick. The southeastward dip of the strata carries the limestone below drainage on North Fork near the mouth of Devil's Fork.

Vigorous prospecting for fire clay has recently been done on North Fork, Bucket creek, Minor, Pretty branch, and Craney creek. Most of these openings were visited by the writer and while the fire clay was seen at only one place, the following notes will show the nature of the contact between the limestone and the Conglomerate. This region was doubtless near the edge of the basin which extended from here to the Ohio river and beyond when the fire clay was forming. The regularity of the Mississippian limestone in the southwestern part of the fire clay area indicates that there was less erosion interval between the deposition of the limestone and the Conglomerate than was the case in the central district. The thickest and best fire clay deposits of the Olive Hill district are found where there is evidence of the greatest time interval and erosion beween the deposition of the Mississippian limestone and the Conglomerate.

LIMEKILN POINT.—The base of the Mississippian limestone occurs in the railroad cut at Limekiln Point. Six feet of the Waverly sandstone are exposed in the lower part of the cut, separated from the Mississippian limestone at this point by a bed of blue shale six feet in thickness. The contact between the two formations is very similar to that found at Deep Cut on the Carter-Lewis County line mentioned in this report.

BOOKER BRANCH.—While in the district the writer was shown a number of samples of lithographic stone said to have come from Elliott and Rowan Counties. At the mouth of Booker branch there is a bed of lithographic stone ten feet in thickness. It is of Mississippian age and lies just above the six foot bed of blue shale which comes between the limestone and the Waverly. The limestone above the lithographic stone is very hard and studded with flint nodules. The lithographic stone was tested and found too soft and porous for lithographic work.

A short distance up stream from the mouth of Booker branch an opening was made for the fire clay at the contact between the Conglomerate and the underlying limestone. A bed of green shale occupies the interval between the two formations.

BUCKET BRANCH.—Two openings have been made at the fire clay horizon on Bucket. One is on the right and the other on the left fork facing up stream. The opening on the right fork is of a dark blue color and contains a large amount of sand.

The opening made on the left fork shows the best fire clay found in this region. The following is a section of the opening:

	Feet.
Conglomerate sandstone.	
Coal	1½
Siliceous claystone and black plastic clay	5
Coal	1½
White to gray boulder flint clay	4
Semi-hard clay	2
Siliceous fire clay	3

DEVIL'S FORK.—At the mouth of the Devil's Fork an opening was made at the contact between the Conglomerate and the Mississippian limestone. Ten to twelve feet of blue fosiliferous shale with a twelve-inch band of hard limestone form the interval between the two formations. The unconformity here is between the blue shale and the Conglomerate sandstone. The limestone disappears below drainage on North Fork a short distance above the mouth of Devil's Fork.

The strata between the mouth of Devil's Fork and Pretty branch have a strong dip down stream or to the north west. The general dip of the strata in this region is to the southeast, but the reverse dip between the two points mentioned is very pronounced.

PRETTY BRANCH.—About one-fourth of a mile up Pretty branch the fire clay was recently uncovered. The base of the Conglomerate was not shown in the opening, but about five feet below the Conglomerate, a bed of greenish flint was encountered. At the surface it is somewhat more siliceous than the gray flint clay, but further development may show a better grade of clay. An eight foot bed of blue shale was uncovered below the fire clay. Bands of red shale six inches thick are found interbedded in the blue shale.

CORY STATION (MCGLONE P. O.).—The fire clay and the Mississippian limestone outcrop along the upper

waters of Gorman Fork to within one-third of a mile of Cory. About one and one-fourth of a mile east of Cory, on Nolan branch, on Mr. J. P. Whitt and Sons' land, is a deposit of fire clay which was opened about 1904. An opening was made 25 feet into the hill and shows five feet of flint clay. The Conglomerate sandstone forms the roof of the clay. The thickness of the clay and its accessibility to transportation would justify a thorough investigation. The samples taken were from near the crop and are not representative of what may be expected farther under the hill. The clay is well above drainage and has plenty of covering above it.

GRAHN.—The clay mines in the vicinity of Grahn were among the first opened in the Olive Hill district. They are owned and operated by the Louisville Fire Brick Works, of Louisville. The mine now operated is located on the north side of Grassy Fork, one-fourth of a mile up the stream from Grahn Station.

The Mississippian limestone outcrops on the south side of Grassv and extends a short distance above the clay mine. It can be traced more or less continuously from a point a short distance below Cory station on Gorman Fork to near the mouth of Dry Fork below Aden. It also extends about two miles up Dry Fork.

The Conglomerate sandstone is not found on the lower waters of Cory Creek on the west side of the divide between the waters of Tygart creek and Gorman Fork. On the waters of the latter stream it extends unbroken to about one mile east of Leon where the eastward dip carried it below the surface. In the vicinty of Grahn it is about 70 feet in thickness.

Near the entrance of the clay mine at Grahn the Conglomerate rests directly on the fire clay. Farther in the hill the bed of shale with the thin coal at the base comes between the clay and the Conglomerate sandstone. The clay is of a poorer quality where the sandstone forms the roof of the clay. In such places there is a large amount of iron in the clay which burns to a red or black color. The shale where it forms the roof of the clay, protects the clay from the iron-bearing waters which filter through the Conglomerate.

The bottom of fire clay is very uneven due to the irregular surface of the limestone on which the clay was formed. In places there are funnel-shaped depressions, wide at the top and tapering to a point at the bottom, very similar in shape to the sink holes so common in some of the limestone regions of western Kentucky. This is the only place in the district where such depressions were found. In some of these depressions the clay thickens to twice its normal thickness. In other places the limestone lumps up and almost cuts out the clay. In no place, however, has the clay been entirely cut out. This irregularity in the bottom of the clay occurs in the southwestern part of the mine. In the northeast portion the limestone has given no trouble. The shale roof is softer here than in the southwestern part of the mine, but the quality of the clay is better.

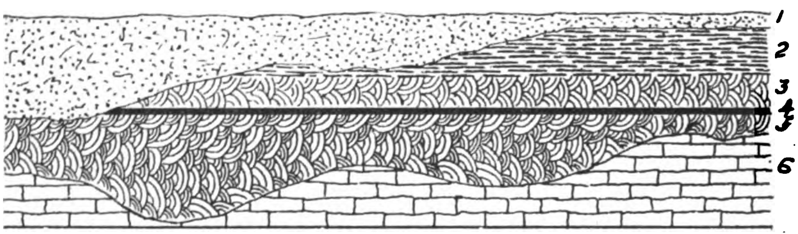


Fig. 5.

Section of Louisville Fire Brick Work's Mine, Grahn, Ky.

1. Sandstone.
2. Shale.
3. Plastic Clay.
4. Coal.
5. Plastic Clay.
6. Limestone.

On coming east the little coal which was one to two inches thick at Olive Hill has thickened to eight inches in the mines at Grahn.

Four grades of clay are found in the same bed here. The No. 1 flint clay varies in thickness from a knife edge to 9 feet. In places the flint is entirely replaced by the No. 2 clay. The latter is a white plastic clay which is the most uniform of any clay found in the mine. However, it varies from 2 to 6 feet in thickness, and in a few places it is entirely absent. Number 3 clay is a red plastic clay

which lies beneath the No. 2 and varies from 1 to 4 feet in thickness. Number 4 is a gray to dark plastic clay which comes above the coal. It is mined and used with the other clays. It varies in thickness from 0 to 5 feet. It is the most irregular of any of the clays.

The average thickness of all of the clays is 6 feet. Where No. 1 is thick the others are thin. Where one clay thickens the others thin correspondingly.

The company is now erecting a 7-kiln fire brick plant at the junction of Grassy and Gorman Fork a short distance above Grahn station, to be known as the Grahn Fire Brick Works. A spur from the Chesapeake and Ohio Railroad is built from the station to the tipple at the mouth of the mines. The kilns are built on the north side of the plant beside the spur and the bricks from the kilns can be loaded directly into the cars. The plant will be equipped with one dry pan, two wet pans, and one brick machine. The daily capacity will be 32,000.

The fire clay horizon extends eastward from Grahn to Aden. The Conglomerate above and the limestone below the fire clay may be seen more or less continuously between these places. Between Grahn and Aden the Chesapeake and Ohio Railroad Company has cut a tunnel through a small projection of the hill at the level of the fire clay. The following is a section at the tunnel:

	Feet.
Rotten shale	7
Coal	1
Fire clay of poor quality	11
Iron ore	1¼
Flinty limestone in beds six inches to three feet in thickness	8

ADEN.—The fire clay was worked at Aden for about 20 years, but the work was shut down at the time of writer's visit. The clay was shipped principally to the Louisville Fire Brick Works, of Louisville.

The mine was opened under the heavy-bedded Conglomerate sandstone which forms a high cliff at Aden. The thickness of the clay varies from 3 to 7 feet with a general average of 4½ feet. The roof of the mine is shale with the thin coal below. In places, however, there

is a dark plastic clay which comes above the coal. It is refractory and was mined and used with the other clays.

Where this is present there is a corresponding thinning of the shale.

The coal at the top of the clay in the Aden mine has thickened to 26 inches and has a shale parting one or two inches in thickness.

Mr. Saulsbury, the owner of the mine, reports that about one-tenth of the clay of this mine was flint and the remainder plastic.

PRATER OPENING.

Two miles north of Aden on Dry Fork an opening was made on the fire clay on the Prater land. The entry was driven 180 feet into the hill. The coal here is two feet thick and was used locally for fuel. The following section was made at the opening:

	Feet.
Shale roof.	
No. 4 fire clay	2
Coal	2
Flint clay	2
Semi-hard clay	2
Pink eye clay.	

MADDIX CLAY.—On Mr. P. F. Maddix's land on the north side of Big Sinking creek, near the mouth of Maddix branch, is an exposure of fire clay which is 20 to 25 feet thick from the top of the coal. Fragments of the flint clay have rolled down the hill, but it is not possible to determine the thickness of the flint.

About one mile south of Aden, near the ford across Big Sinking, Mr. Maddix drove a twenty-yard entry on the fire clay. The clay was found to be 8 feet thick with 15 to 24 inches of flint clay. The coal here is 16 inches thick. The Conglomerate sandstone forms the roof of the mine.

Farther up the creek Mr. Maddix worked the clay for a short time. An extra fine quality of white flint clay was obtained at this old pit.

The most eastward extension of the fire clay and Mississippian limestone found on Big Sinking was found

on the south side of the stream just above the mouth of Halls branch. The top of the limestone is here near the water's edge. It is reported, however, that the clay and limestone occur on Mr. Ike Isom's land, ¼ mile below the mouth of Hall's branch.

A number of openings have been made on the fire clay on Big Sinking to the south and southeast of Olive Hill. The region is so inaccessible, however, that the clay can never be utilized without a railroad up that stream. The clay where seen by the writer, is of good quality, and the deposits are sufficiently thick to be profitably mined if there was any means of getting it to market.

A road leading south from Olive Hill to Big Sinking up Ben's Run crosses a high divide which is 405 feet above low water in Big Sinking at Joseph Field's house below the mouth of Spruce branch.

The clay has been opened on Joseph Field's place at an elevation of 800 feet above sea level. Flint clay was found on the old clay dump, but the thickness of the bed could not be determined.

The following instructive section was made along the road from Joseph Field's house on Big Sinking to the top of the divide near the head waters of Ben's Run. The elevations given were determined by the barometer and are subject to change.

1115 A. T.	Top of highest hill.
	Shale.
1080 A. T.	Coal bloom.
	Shale.
1045 A. T.	Thin bed of sandstone.
	Shale.
1040 A. T.	Coal bloom.
	Shale.
1010 A. T.	Four-foot vein of coal which is now being worked.
	Shale.
990 A. T.	Thin coal.
	Shale interval.
985 A. T.	Thin bedded sandstone interval.
920 A. T.	Top of Conglomerate sandstone.
	Conglomerate sandstone interval forming steep cliffs.
800 A. T.	Base of Conglomerate and fire clay horizon.
	Heavy bedded limestone interval.
710 A. T.	Bed of creek in Big Sinking.

A 5-foot bed of fire clay is reported to have been opened on Jno. Baker's land near the mouth of Dudley branch. A number of other openings of fire clay have been made in this region of Big Sinking but the writer did not see them.

BARRETT'S CREEK.—Barrett's creek rises within two miles of Tygart creek, flows in a general easterly direction and empties into little Sandy river about one and one half miles below Grayson.

In its upper course the stream has cut through about 350 feet of Coal Measure rocks and exposed the top of the Mississippian limestone for a distance of about two miles on main Barrett above the mouth of Smith branch, and for about the same distance on the latter stream.

The flint clay has been opened on main Barrett a short distance above Bull's Eye spring. A heavy bed of shale forms the roof of the clay. The Conglomerate is not exposed in the region where the limestone occurs. The elevation of the clay, barometric reading, is 750 feet above sea level.

The crest of the divide between Barrett creek and Tygart creek is 1,100 feet above sea level.

On the west side of the divide the Conglomerate forms precipitous cliffs along Tygart creek 85 to 100 feet high.

The Mississippian limestone on Tygart at the mouth of Smoky Fork is 75 feet thick. It thickens on Cave branch to 110 feet. About 60 feet of Waverly are exposed at this place.

CAVE BRANCH.—About one-half mile up Cave branch on the south side of the stream the Conglomerate sandstone rests directly on the limestone without any fire clay, shale or iron ore between.

SUTTON BRANCH.—Two miles up Sutton from its mouth the fire clay occurs on Mr. N. F. Burris' land at an elevation of 940 feet above sea level. A short distance above this, on Mr. James McGuire's land, the fire clay outcrops in a number of places. At an exposure on the west side of the road just above his house the clay is 13 feet thick with five feet of flint of good quality and the remainder is a yellowish plastic clay, and "pink eye" at

the base. At the base of the pink eye is a five-inch bed of carbonate of iron.

The Conglomerate and the limestone are both prominent on Sutton. The Waverly extends up the stream from its mouth for a distance of only two miles.

BUFFALO FORK.—On Mr. Joseph Pence's land, one mile east of Carter on a branch of Buffalo Fork, the flint fire clay has been opened showing the following:

	Feet.
Conglomerate to top of hill.	
Covered	8
Flint clay of oolitic structure	4
Impure sandy flint	1½
"Pink eye" clay.	

The elevation of the Pence opening is 1,030 feet above sea level. This opening was made on the south side of the hill. An old opening was formerly made on the east side of the same hill below the Conglomerate. At the extreme north end of the hill facing Buffalo Fork, the clay has recently been opened by some parties from Carter County. It was found at two horizons, one at the base of the Conglomerate and the other about twenty feet above in the Conglomerate. Weathered fragments of flint clay were found around the east side of the hill twenty to thirty feet above the base of the Conglomerate.

DEEP CUT.—The elevation of the crest of the ridge between the waters of Kinniconick and those of Smith's Creek is 1,300 feet above sea level, barometric reading. The Chesapeake and Ohio Railroad crosses the divide at this point through what is known as Deep Cut. About twenty-eight feet of Waverly are exposed. The Mississippian limestone is eighty feet thick with a ten-foot bed of red shale between the two formations. The elevation of the top of the limestone is 1,240 feet above sea level.

CARVER CLAY PIT.—At a point on the road one-half mile south of Deep Cut at an elevation of 1,240 feet above sea level is an old clay pit which is known as the Carver clay pit. It was worked about twelve years ago by Mr. William Cooper and the clay shipped to Covington, Ashland and Huntington. The clay is all of the flint variety.

Some of it is of an oolitic structure; some is red and some a clear white with a dense smooth texture.

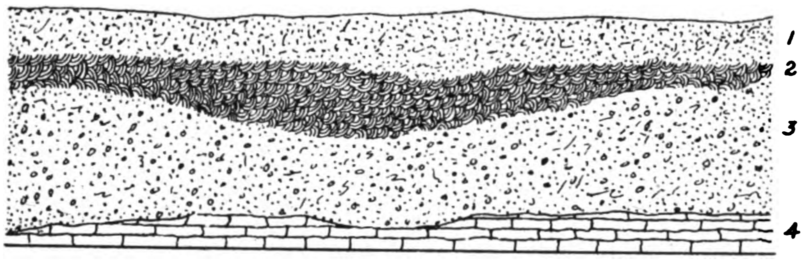


Fig. 6.

Section at Carver Clay Pit, showing Conglomerate under Flint Clay.
1. Sandstone.
2. Flint Fire Clay.
3. Conglomerate.
4. Limestone.

On the west side of the road, and less than 100 yards from the old clay pit, the Conglomerate forms a bold cliff, which is forty feet high. The relation of the clay to the Conglomerate is shown in the following section:

	Elevation Above Tide.
Carver Clay pit	1240
Top of Conglomerate sandstone	1220
Top of Mississippian limestone	1180

There is a pronounced southward dip of the rocks as shown along the road from Deep Cut to the Carver Clay pit. No clay of any consequence was observed between the Mississippian limestone and the Conglomerate at Deep Cut or at the Carver pit.

RILEY CLAY OPENING.—About one mile west of the Carver clay pit on the west side of the road, the flint fire clay has been opened. According to the barometer the elevation of the clay at the latter place is ten feet lower than it is at the Carver pit. The clay occurs beneath a three-foot ledge of sandstone, the lowest two inches of which is brecciated with angular fragments of flint clay. The clay deposit is six feet thick and all flint except eight inches of plastic next to the sandstone roof.

"OLD AIR FURNACE."—The limestone is present along the county line on the headwaters of Brushy creek at an elevation of 1240 feet above sea level. The highest hills rise about 60 feet higher. The flint fire clay was said to have been mined at "Old Air Furnace," on the county line at the head of Brushy, and used at Boone Furnace Works for lining the furnace. An old pit with fragments of flint fire clay on the dump marks the location of "Old Air Furnace." The clay is very dense and resistent to the weathering agents. It is oolitic in structure. Limestone outcrops on the hillside twenty feet below.

GRASSY CREEK.—A deposit of flint clay has been opened on the north side of Grassy creek, about one mile from Boone Furnace. The clay has been uncovered to a depth of fourteen feet with no trace of plastic clay above or below. It is a white clay of a dense, smooth structure with apparently no iron or other impurities. On exposure to the elements it weathers into small rectangular blocks. The deposit is near the top of the ridge. The Mississippian limestone is present on the opposite side of the hill twenty to thirty feet below the flint clay. The elevation of the clay opening is 1,160 feet above sea level.

The following is a section of the strata at the head of Grassy Creek made by A. R. Crandall in the report on the Geology of Greenup, Carter and Boyd Counties, Kentucky Geological Survey. Section 6, plate No. 3:

	Feet.	
Top of Hill.		
Coarse sandstone	about 20	40 feet
Fire clay	about 7	
Dark shale	about 5	
Sandstone	about 5	
Limestone ore	about 3	
Sub Carboniferous limestone	90	
Waverly.		

The following analyses show the quality of the clays from this region:

	No. 1	No. 2	No. 3	No. 4
Silica	45.96	45.56	54.62	48.56
Alumina	38.53	43.77	32.46	37 47
Oxide of iron	Tr.	Tr.	Tr.	Tr.

Lime	.14	.14	Tr.	.11
Magnesia	Tr.	Tr.	Tr.	Tr.
Phosphoric acid	Tr.	Tr.	Tr.	Tr.
Potash	.25	.96	.21	.28
Soda	.34	.72	.67	.28
Loss on ignition	14.21	8.52	11.78	13.03

Analyses from Kentucky Geological Survey Reports.

The flint clay is reported to be present on both sides of Three Prong Creek and also on the waters of Leatherwood creek.

A fourteen-foot deposit of flint clay is reported on the south side of Lost creek near Tygart creek about one mile west of She Bear creek.

ZORNES BRANCH.—Near the mouth of Zornes branch the fire clay outcrops in the road on Garrette Zornes' place. The outcrop here shows about twelve feet of flint clay. Here as at the other localities in northern Carter County the clay is up in the Conglomerate and not at the contact between the Conglomerate and the Mississippian limestone. The Conglomerate forms a cliff around the hill below the fire clay and is also present above the clay. The clay has never been opened and its quality cannot be determined by the surface exposure.

ROCK SPRING CREEK.—A bed of flint clay has been opened on Mr. W. F. Partee's land on the west side of Rock Spring creek, about one mile south of the mouth of Zornes' branch. Two openings have been made on the fire clay at this place. The lower one is at the top of the Mississippian limestone horizon at an elevation of 925 feet above sea level, and the other up in the Conglomerate twenty-five feet higher. The upper one is a hard, impure flint clay of a greenish cloudy effect. The green color is due to the presence of ferrous iron and vegetable matter. The lower clay is of a gray color.

IRON HILL.—A deposit of flint clay outcrops on the east side of the road on Clark branch about one mile north of Iron Hill. The Mississippian limestone is absent here and the clay rests directly on the Waverly. However, the limestone is present farther down the branch. The following section was made of the outcrop. Elevation of the clay 875 feet above sea level.

	Feet.
Flint clay	2
Red shale	2
Blue shale	5
Thin bedded sandstone and shale to bed of branch.	

The flint fire clay has been uncovered on Mr. William Newman's land on Stump's Run three-fourths of a mile east of Iron Hill. The elevation of the clay at this place is 825 feet above sea level, or 115 feet above the bed of Tygart creek at Iron Hill bridge. The following is a section of the opening:

	Feet.
Iron ore	½
Plastic clay	3
Boulder flint clay	5
Pink eye.	

EVERMAN'S CREEK.—Everman's creek, like Barrett's creek to the south, has cut through the Coal Measure rocks and exposed the Mississippian limestone for about three miles of its course. A small fold brings up the limestone within about one mile of the headwaters of the stream. It outcrops on main Everman and for about one mile up Stewart branch. It continues down the main stream for about three-fourths of a mile below the mouth of Stewart branch and then dips under the level of the creek. It appears again farther down the stream a short distance above Wolf Pen branch and continues to near the mouth of the Right Fork of Everman.

A deposit of flint clay has been opened on the north side of Everman's creek about one mile above the mouth of Stewart branch. The clay is about four feet thick and is overlain by ten feet of black shale. The quality of the clay is poor due to the amount of iron contained in it.

At Adkins Post Office, near the mouth of Stewart branch, the clay occurs in the form of a very hard flint of a cloudy blue color known as "calico clay." On exposure to the weathering agents it does not disintegrate like the pure No. 1 flint. It forms a small fall in the branch in front of the Post Office where the clay is six feet thick. The upper part of the deposit is of an amorphous struc-

ture similar to the other deposits of the district: the center and the lower portions are in stratified layers.

The stratified portion of this deposit has a structure that was not observed in any other deposit in the territory. It consists of a series of parallel joints which extend in a northeast and southwest direction with another set at right angles to the first.

It will be seen from the description of the clays of northern Carter County that the deposits are numerous and in many places of great thickness, but the quality of the clay is not as uniform as it is in the territory around Olive Hill and in the southwestern part of the county. Some of the analyses of the clays from the Boone Furnace territory show the clay to be of exceptional purity. In most of the other localities, however, the blue or greenish clay is present in greater or less quantities. It is practically worthless on account of the great amount of iron it contains.

OLDTOWN CREEK.—A bed of flint fire clay is reported to overlie the Mississippian limestone near the headwaters of North Fork of Oldtown creek in Greenup county.

COAL BRANCH.—Coal branch is a small stream that rises within a mile of Tygart creek, flows due east and empties into the Ohio river one mile above Greenup. The Waverly outcrops on the hillsides and in the bed of the stream for about three miles up the creek. The Mississippian limestone was not observed on Coal branch or any of the streams entering the Ohio from Greenup north to Tongs. North of Tongs it forms a thin band in the hills around the point between the Ohio and Tygart creek. West of Tygart creek in Greenup County, the limestone is present on all of the streams south of Big White Oak creek. From here to the Ohio river it is found only on the headwaters of the largest streams.

However, in all of the territory of Greenup County where the Waverly is present there is a considerable amount of siliceous flint covering the hillsides below the base of the Coal Measure rocks. The limestone was evidently deposited over this territory and subsequently eroded before the deposition of the Coal Measure rocks. The flint contained in the limestone was less easily de-

composed by the weathering agents and was left behind as the remnant of the former great mass.

A number of fire clay openings have been made on Coal branch. The clay is of Coal Measure age as it occurs in shales and sandstones above the top of the Waverly. In most places there is a bed of coal below the fire clay.

The clay contains a considerable amount of free silica, and iron, the latter giving it a greenish color. The clay is of a brecciated nature containing angular fragments of flint in the clay matrix, similar to the clay deposits found up in the Conglomerate in northern Carter.

BIG WHITE OAK.—Flint clay is present on Tygart creek opposite the mouth of Big White Oak at an elevation of 190 feet above low water in Tygart creek. The thickness of the clay was not determined. The clay horizon is marked on the hillside by a pronounced bench which is near the top of the Waverly.

Three miles up Big White Oak on Mr. J. W. Thompson's land near Truitt P. O., the fire clay outcrops at an elevation of 200 feet above the stream. The clay is about six feet thick. The bottom of the clay is highly siliceous and of poor quality.

The Harbison-Walker company have opened the clay on the headwaters of Big White Oak near the site of the Old Kenton Furnace where it is reported to be of better quality but is inaccessible at the present time.

MCCALL.—Charles Taylor's Sons of Cincinnati have a fire brick plant at McCall on the main line of the Chesapeake and Ohio Railroad near the mouth of Tygart creek, two miles above South Portsmouth.

The clay used at this plant is obtained on the south side of Schultz creek six miles south of the plant. The clay is conveyed from the mine to the plant over a narrow gauge railroad in cars drawn by a small engine.

The mouth of the mine is 245 feet above the bed of Schultz creek and 100 feet below the top of the hill. There is a strong eastward dip in the mine of eight feet in sixty. The eastward dip continues for only a short distance where there is a reverse dip.

The clay from this mine is of an inferior quality to that found in the vicinity of Olive Hill. The flint clay

contains free silica and there is so much iron in it that the bricks made of it are spotted and off color generally. Many of the bricks burn dark. The following is a section at the mine:

	Feet	Inches.
Coarse grained sandstone to top of hill	100	
Shale	8	
Coal	....	2-6
No. 2 plastic of a dark blue color	3	
No. 1 flint	5	6
"Pink eye" clay.		

The hillsides below the mouth of the mine are covered with angular fragments of flint, but no limestone was observed.

The brick plant at McCall has seven rectangular, down-draft kilns of 60,000 capacity each and one round, down-draft kiln of 30,000 capacity. The daily output of the plant is 20,000 bricks. There are two wet mud pans and one dry pan. The clay is first ground in the dry pan and then conveyed by an endless belt to the wet mud pans where it is mixed with water and pugged for twenty minutes into a stiff mud. The bricks are all molded by hand. One man molds 4,600 standard sized bricks a day. The bricks are dried on a cement floor heated from beneath. It requires about seven days for burning a kiln of bricks.

The calcine, the No. 2 plastic and the best grade of flint used at this plant come from Olive Hill. These are mixed with the clay from Schultz creek. A very desirable brick is made of seventy parts of No. 1 flint, nine parts of No. 2 plastic and six parts of calcine.

DRY RUN.—The flint fire clay was formerly mined on the east side of Tygart creek opposite the mouth of Dry Run and also on the west side of Tygart between Dry Run and Plum creek. The clay was hauled to the Ohio river at Edgington and shipped to the Adams Fire Brick Plant at Portsmouth.

ROCKY BRANCH.—About eight years ago Messrs. Edgington, Lou Art and J. Johnson opened a clay mine on the south side of Rocky Branch facing the Ohio river. Two kilns were built here and the clay was calcined and shipped to Steubenville and to Pittsburg for glass-pot making. The opening was driven 180 feet into the hill.

The clay is six feet thick at the old opening and is said to be of good quality. It occurs beneath a good shale roof with a 14-inch seam of coal between the clay and the shale. The mine was operated for two years and then abandoned.

LIMEVILLE (TONGS P. O.).—The Mississippian limestone is present in the high hill facing the Ohio river just back of Limeville. The flint fire clay horizon here is composed of a thin bed of green shale, which is apparently refractory. The heavy bedded limestone has been recently utilized by the Wilson Ballast company for making railroad ballast. The following section was made at the crusher:

	Feet.
Beds of siliceous shale interbedded with ledges of coarse-grained sandstone	65
Hard siliceous brecciated sandstone containing plant remains	5
Irregular wavy bed of green siliceous shale weathering in places to a deep red color. Iron ore is found imbedded in the shale. There is a marked unconformity between this horizon and the one below	2-5
Mississippian limestone	30
Waverly to bottom of the hill	280

ASHLAND DISTRICT.

The Ashland district, as previously stated, includes the fire clay deposits associated with the coal seams which occur in the area included in this report. The lower part of the coal measure rocks overlie the fire clays of the Olive Hill district, but the fire clays of economic importance of the Ashland district occupy a well defined area, the western limit of which is from four to ten miles east of the most eastern outcrops of the Olive Hill fire clay.

The most important fire clay deposit of the Ashland district is that associated with the Ferriferous limestone. The outcrops of the limestone and the clay occur in the hills a short distance east of Little Sandy river from the Elliott county line to the Ohio river. The area increases in width from about two miles in the southern part to about fourteen miles in the northern part. The clay is found in all the high hills facing the Ohio river from the

mouth of the Big Sandy to near the mouth of Yewlands creek, four miles above Greenup. The rise of the strata to the northwest carries it beyond the tops of the hills west of Little Sandy river.

Southeast of the area described the dip carries the fire clay below drainage level. The clay is found in well borings at increasing depths as the distance from the surface outcrop increases.

The fire clay deposits of this district are finely comminuted sediments which have reached their present position through the agency of water. They occur as horizontal beds and usually form the floor of coal seams.

There are three grades of fire clay found in the Ashland district. These are: the No. 1 plastic, the No. 2 plastic, and the flint. The latter occurs in thin bands through some of the plastic beds, and composes a very small per centage of the whole.

There are three areas of the Ashland district where the fire clay has been worked. These are at Willard, near the southern border; at Hitchins and Denton, near the center; and at Ashland and Catlettsburg, on the Ohio river. A description of the mines and the fire brick plants of the district will be given in detail.

WILLARD.—The Ferriferous limestone outcrops on either side of Little Fork in the town of Willard. Resting directly on the limestone is a bed of plastic fire clay which has been mined in two places in the town of Willard.

At the northern edge of town Dr. H. B. Fraley opened a mine on the fire clay and operated it for some time, but had to abandon it on account of excessive freight rates and the low price of clay. The mine was located on the east side and about twenty feet above the track of the Eastern Kentucky Railroad. The clay was drawn out of the mine in small cars and loaded directly into the cars from a tipple.

The clay is reported to be of good quality and is a valuable clay when used with flint clay and calcine. It is a highly plastic variety and has a high shrinkage when used alone.

At the eastern edge of Willard the Willard Fire Clay Company opened and operated a clay mine at the same

geological horizon as the Fraley mine. Clay was shipped from here for some time, but excessive freight rates and the low price of clay made the work unprofitable.

The mine was worked by drift. At the mouth of the mine, which is now closed, the clay is five feet thick. At the surface the clay was slightly stained with ferric oxide, but farther in it is reported to be of a light gray to bluish color. The lower third of the bed is of lighter color and harder than the upper two-thirds. A thin seam of coal is reported near the top of the clay.

Just below the Ferriferous limestone in the western edge of Willard, at the foot-bridge across Little Fork, is a deposit of black shale eight to ten feet in thickness. At the base of the shale is a thin coal which rests directly on heavy bedded sandstone. Near the top of the shale is a thin deposit of plastic fire clay with a band of flint clay between the plastic clay and the limestone. The shale and fire clay below the limestone would make an excellent material for sewer pipe. Samples of the raw clay and the shale have been tested for this purpose with good results. Could satisfactory freight rates over the Eastern Kentucky Railroad to Hitchins be obtained, this would be a desirable location for the erection of a sewer pipe or paving brick plant. Fuel for such a plant could be obtained at a minimum cost from coal mines which are now being operated in this locality.

The following analysis of the fire clay from Willard is given on page 116, Bulletin 349, U. S. Geological Survey. The analysis was made by C. H. Stone at the structural materials testing laboratory, U. S. Geological Survey, St. Louis, Missouri.

Silica	60.54
Alumina	25.89
Ferric oxide	1.75
Manganese oxide	.26
Lime	.53
Magnesia	.12
Potash	1.85
Soda	.65
Water	2.05
Loss on ignition	7.43
Sulphuric anhydride	.12
	101.19

HITCHINS.—The Olive Hill Fire Brick Company is now constructing at Hitchins what is said to be the largest fire brick plant in the world. The plant is located at the junction of the Cheaspeake & Ohio and the Eastern Kentucky Railroads. No amount of money has apparently been spared in making it one of the most up-to-date plants of its kind.

The floor space of the main dry room is 156 by 192 feet. In addition to this there is a large power house, which contains a 350-horse power engine and 400-horse power boiler; a pan room, and an apparatus house. The pan room contains two large dry pans, two pug mills and two large brick machines. Most of the bricks will be machine-made. The apparatus house contains one 14-foot steel induction fan, and an exhaust fan 12 feet in diameter. These will used to control the waste heat from the kilns in drying the bricks.

The entire structure is made of steel and concrete frame, with walls of cement plastering on steel Hy-rib, and covered with asbestos-protected metal roofing.

Each piece of machinery will be run by a separate dynamo.

The company now has ten 30-foot round, down-draft kilns of 80,000 bricks each capacity, and it is the intention to erect in the near future ten more of the same size. The kilns are built twin-fashion and the waste heat, after a kiln of brick is burned, will be conducted through a main cement-lined tunnel to the dry shed, where it will be used to dry the green bricks. The waste heat from any kiln can also be conducted to any other kiln and there used for drying the green bricks. Each kiln is made separate or thrown into the main hot air current by means of a steel damper.

The purpose of the induction fan is to draw the waste heat from the kilns and force it to the dry room. A part of this heat will be conducted through flues leading off from the main tunnel beneath a stone floor which is constructed of Rowan county sawed stone. The green bricks will be laid on this smooth floor to dry. Opposite the dry floor are twelve small tunnels constructed at a right angle to and connected with the main tunnel. These tunnels are 100 feet in length and are built air tight. They are

constructed with tracks of one per cent grade so that small cars of green bricks can be pushed in and dried on the cars. The cars will be pushed in the tunnels from the end next to the pan room where the bricks are to be made. When dry enough to set in the kilns they will be forced on through the tunnels to the kilns and the tunnels refilled as before.

The heat from the main tunnel can be directed to the dry floor or to any set of tunnels by means of deflector dampers.

The 12-foot exhaust fan will draw the heat from the dry floor and the small tunnels through a return tunnel and force it out through a large stack built at the apparatus house for that purpose.

In case there should not be sufficient waste heat from the kilns to dry the bricks, it is arranged to dry a part of them by means of exhaust steam.

The daily capacity of the plant when completed will be 100,000 bricks.

The plant was designed by the L. E. Rodgers Engineering Company, of Chicago, and constructed under the supervision of Clayton S. Hitchins, of Olive Hill.

The company owns about 450 acres of land lying to the east of the plant. The clay to be used at the plant is expected to be derived from the bed associated with the Ferriferous limestone. At Willard, at Denton, four miles east of Hitchins, at Ashland, and at Music, the fire clay of the Ferriferous limestone horizon is near the base of the hills and is found in continuous beds of good quality. Hitchins is located at the western border of the area underlain by the limestone and associated clay. The first hills to the east of the plant are not high enough to catch the limestone and the clay. About one mile east of the plant the highest crest rises 300 feet above the plant. Seventy feet below the crest the fire clay has been uncovered at about the horizon of the Ferriferous limestone. The place is marked by the presence of old iron ore diggings. The clay occurring as it does within 70 feet of the crest of the highest ridges, there is a very small proportion of the land owned by the company underlain by the clay. The main body of the clay lies to

the east where the eastward dip carries it down near the base of the hills and gives a larger workable area.

It will require a large area of workable clay to supply the demand of a plant that is to produce 50,000 to 100,000 bricks a day for an indefinite length of time. There are three possible sources where clay may be obtained. The plastic variety may be obtained in the hills farther east in the vicinity of Denton and Music, and on the head waters of Robin Run and Upper Stinson creeks; or it could be obtained to the south in the vicinity of Willard. If flint clay is to be used the nearest deposits would be in the Big Sinking creek territory or in the hills south of the Chesapeake & Ohio Railroad between Cory and Grahn. The hills between Dry Fork and Grassy Fork of Gorman Fork may be worthy of further investigation.

There is also a possibility of getting the Olive Hill flint clay below the surface at Hitchins. It was found to be ten feet thick in one of the oil wells at Denton. It occurred just above the Mississippian limestone with fifteen feet of blue shale above the clay and between it and the Conglomerate sandstone. The fire clay was struck at a depth of 625 feet below the surface. The rise of the strata to the west would bring the Olive Hill flint clay horizon to within about 350 feet of the surface at Hitchins. Could it be found of good quality and seven to ten feet in thickness, it would be more economical to mine it even at that depth than it would be to haul it from the Olive Hill district. Its presence or absence could be determined by means of a core drill.

Considerable excavation has been done in the hills east of the plant in an effort to locate the fire clay deposits. The following is a section of the hill from near the "Blue Jay" coal mine to the clay opening at the head of the branch. The entire thickness of the section is about 300 feet.

		Feet	Inches.
28	Crest of high hill.		
27	Covered. Ferriferous limestone comes near base	70	
26	Plastic clay containing thin irregular pockets of flint clay	25	

		Feet	Inches
25	Gray laminated shale which weathers to a bluish clay	2	
24	Gray plastic clay with two inches of dark clay in the center	1	
23	Black shale	....	21
22	Coal	....	13
21	Irregular bodies of stratified clay	4	
20	Pale drab stratified fire clay	....	20
19	Dove colored fire clay with streaks of iron oxide	....	12
18	Dove colored fire clay, uniform in color	....	18
17	Gray micaceous sandstone about	15	
16	Covered	....	
15	Sandstone	....	
14	Shale	3-4	
13	Coal	....	1
12	Draw slate	1	
11	Coal	....	21
10	Bone	....	3
9	Coal	....	14
8	Fire clay	....	
7	Shale	25	
6	Sandstone changing to shale at same horizon	50	
5	Gray shale	25	
4	Coal	....	3
3	Sandstone, hard on bottom and shaley on top	6	
2	Black shale	20	
1	Sandstone.		

The fire clay occurring from 18 to 21 inclusive is the most promising horizon of the section. At horizon 26 is a deposit of laminated, micaceous shale which contains irregular blocks of flint clay. In places it occurs in kidney-shaped forms. The color is not uniform, but shows finely stratified lines of white, light gray to dark gray sand in the clay.

The quality of the clays from the Hitchins property is shown in the following analyses and tests made by J. M. Knote, of the Pittsburg Testing Laboratory. The following results and remarks of J. M. Knote were kindly furnished the writer by Mr. Hitchins, General Manager of the Olive Hill Fire Brick Company, Olive Hill:

	Loss on Ignition.	Silica.	Oxide Iron.	Oxide Aluminum.	Oxide Calcium	Oxide Magn.	Titanic Acid.	Alkalies.	Fusion Cone.	
1.	12.24	53.30	.71	30.88	.50	.03	2.21	.12	34	3290°F.
2.	8.16	58.90	1.71	26.23	.45	.03	1.28	3.49	24½	3092°F.
3.	10.32	55.48	1.71	27.89	.60	.20	1.48	1.45	28	3182°F.
4.	8.48	64.28	.71	23.51	.50	.08	1.51	.99	31	3182°F.

(1) "Flint clay from bottom seam. Shrank from 12 to 11 1-10 inches on burning. No shrinkage after cone 9. An excellent clay and while a little higher in silica than those at Olive Hill, it should make very good brick. It is as good as the best Missouri, Pennsylvania and Maryland flint clays.

(2) "Plastic clay. Shrank from 12 to 11 inches on drying and to 10½ inches on burning. A very plastic and strong bond clay. It dries with a normal shrinkage and burns to a dense strong body at cone 3 and remains thus without change to cone 11. It would doubtless show little change up to cone 22-25. Its burning shrinkage is normal. The clay is as plastic and strong as any but the exceptional fire clays. It vitrifies three or four cones lower than the Maryland clays, but about the same as most Pennsylvania clays. The Missouri clays are much more porous at cone 11. In refractoriness it is just about the same as the best Savage Mountain clay or Pennsylvania clays. I consider it a very good bond clay.

(3) "Plastic clay. Shrank from 12 to 11 2-8 inches on drying and to 10½ inches on burning. Nearly out at cone 3; all out at cone 7-9. Similar to No. 2 in every way.

(4) "Flint clay. Shrank from 12 to 11 2-10 inches. All out at cone 9. This clay is a second grade flint clay and while of probable value for second grade brick, it is not as valuable as clay No. 1."

DENTON.—In 1908 the Denton Plastic Clay Company, of Denton, opened a clay mine about 200 yards east of Denton, on the main line of the Chesapeake & Ohio Railroad. The mine is located about 200 feet above the railroad track. It is worked by horizontal drift and the clay

loaded into clay cars, which are pushed by hand to a tipple built on a side track of the railroad, and dumped directly into open freight cars.

The raw clay from the Denton mine is shipped to Charles Taylor's Sons, Cincinnati; to the Louisville Pottery Company, Louisville; to the Rookwood Pottery Company, Cincinnati; and to the Harbison-Walker Refractories Company, Olive Hill. The monthly shipments average nine cars of 45 tons to the car.

The clay occurs at the horizon of the Ferriferous limestone although no limestone is present here. It is the same clay that occurs 70 feet below the top of the highest hills one mile east of Hitchins. The following is a section of the mine.

Elevation of mouth of mine 680 feet above sea level.

	Feet	Inches.
Light gray shale.		
Laminated micaceous sandstone	6	
Dark clay	4	
Coal	....	10
Black plastic clay—not worked	5	
Dark, hard, siliceous clay—not used	....	4
Plastic clay containing boulders of silica	8	
Gannister	4	

BURDETTE CLAY MINE.—Mr. J. H. Burdett, of Ashland, in 1907 opened a clay mine one mile east of Denton. The mine is located on the north side of the Chesapeake & Ohio Railroad. It is operated and the clay is loaded into the cars as it is done at the Denton mine. The principal part of the clay is shipped to the National Fire Brick Company, of Strasburg, Ohio.

The geologic horizon of the Burdette mine is the same as the Denton mine, although it is about 70 feet higher elevation. There is a strong westward dip of the strata between the Burdette mine and Denton, as shown by coal number 4 which outcrops at the level of the railroad track at the Burdette switch. For a distance of one-fourth of a mile west of the switch the coal is practically horizontal. Farther west the coal dips rapidly to the west and disappears beneath the level of the railroad track a short distance east of Denton, notwith-

standing a grade to the west in the railroad between the two points of 65 feet to the mile.

The opening of the clay mine is just above a massive, coarse-grained sandstone which is about 55 feet thick at this place. The Ferriferous limestone which comes at about the horizon of the fire clay deposit is absent in this locality. The following is a section at the mine:

	Feet	Inches
Coal of good quality	....	14
Black plastic clay	4-6	
Dark, hard siliceous clay which breaks up into cubical blocks when exposed to the weathering agents and locally known as "Nigger heads"	....	2-4
Good No. 2 plastic clay	6	
Gannister	4	

Hard siliceous gannister boulders are frequently found in the No. 2 plastic clay. In places these boulders cut out part of the clay.

The elevation of the clay mine is about 755 feet above sea level.

About 55 feet above the clay mine is a bed of flint clay. It is marked on the hill side by a distinct bench. Fragments of the flint clay were found at this horizon but the thickness of the deposit was not determined.

MUSIC.—Music is located on the east side of Means Tunnel, two miles east of the Burdette mine. The strata from the Burdett mine to Denton have a strong westward dip, whereas those east of Means Tunnel dip to the east. There is, therefore, a well-defined anticline the crest of which is located near the tunnel.

A deposit of No. 2 plastic fire clay was opened at Music in 1911 on the Lexington and Carter County Mining Company's land in the hill just north of the Chesapeake & Ohio Railroad. Mr. T. M. McGlohon, manager of the property, sent a sample of the clay to the Rookwood Pottery Company, of Cincinnati, and had it tested for making pottery. They pronounced it a very satisfactory clay for that purpose.

The opening from which the clay was obtained was driven 25 feet into the hill. The No. 2 plastic clay is nine feet thick. Weathered streaks of iron oxide extend

through the clay, but do not affect its quality. The clay rests on a siliceous gannister rock similar to that at the Denton and the Burdette mines. A thin coal occurs near the top of the clay.

The elevation of the mine is about 720 feet above sea level.

Two miles east of north of Music a deposit of No. 1 flint clay is reported to have been opened. The deposit is said to be three and a half feet thick.

The clay which occurs at Denton, Burdette mine, and Music is a very persistent formation and may be found underlying a large territory in the hills adjacent to the Chesapeake and Ohio Railroad from Denton to Ashland.

ASHLAND.—The Ashland Fire Brick Company operates two fire brick plants in west Ashland. The larger is known as the Ashland Fire Brick plant and the smaller as the Clinton Fire Brick plant. While they are owned by the same company they are operated as separate plants.

The Ashland Fire Brick Company is located on a spur of the Ashland Coal and Iron Railroad. The clay is dumped from the car as it comes from the mine into a large hopper which contains a grinder, where it is crushed and then conveyed by an overhead electric car to the open yard. Each grade of clay is kept separate. The clay is allowed to remain on the yard exposed to the weathering agents for several months. The weathering mellows the clay, leaches out some of the impurities, and improves its general working qualities.

After the clay is thoroughly mellowed, it is reground in a Clearfield dry pan. The desired mixture of flint clay, calcine and plastic clay are then made and the contents mixed with water and thoroughly kneaded into a stiff mud ready for the molders. The kneading is done in two Clearfield wet pans.

All the bricks made at this plant are hand-molded. The plain bricks are molded and allowed to dry for a certain length of time when they are repressed in hand-power represses. More care is used in molding the shaped bricks and large blocks as they are not repressed. When nearly dry the faces and serrated edges are wet with water and smoothed with a small trowel.

The bricks are dried on a cement floor heated from beneath by exhaust steam from the boiler. No waste heat from the kilns is used in drying the bricks.

The plant is supplied with a 225 horse-power boiler and an engine of the same size. All of the machinery of the plant is run by electricity with a dynamo for each machine.

The output of the plant ranges from 19,000 to 20,000 bricks a day. Four thousand one hundred bricks to the man are considered a day's task, which is accomplished in five to six hours.

The bricks are burned in round, down-draft kilns. There are six kilns with a capacity of 80,000 bricks each. Natural gas is used in burning the bricks. It takes about four days to drive off all of the water and to get the kiln to a good red heat. About two and a half days more are required to bring the kiln to a bright white heat, where it is held for a day and a half. It requires about one day longer to burn the bricks with gas than it does with coal, but the gas gives a more uniform heat throughout the kiln as there is no choking of the draft. On the whole the gas is more economical than coal, in the first cost of the fuel, requires less labor to operate it, is cleaner, and gives a more uniform burn.

The finished product of this plant goes to all parts of the United States, to Canada, Cuba, Old Mexico and Japan.

The clay used at the Ashland Fire Brick plant is derived from two sources. The calcine and the flint clay come from the company's mine at Hayward, in the Olive Hill district. The No. 2 plastic clay comes from the Ashland district. The mine is located in the high bluff facing the Ohio river one mile west of Ashland. The mouth of the mine is about 25 feet above the track of the Chesapeake and Ohio Railroad. The clay is dumped from the mine cars into the railroad cars over a tipple. The clay comes from the same geological horizon as the clay from the Willard and the Denton clay mines. The following is a section of the Ashland mine:

	Feet.
Sandstone	12
Coal	3
Plastic fire clay—not used	2-3
Sandstone	10-12
White to drab potter's clay	5
Shale containing iron ore	4
No. 2 plastic fire clay of a dark color	3½-4
Ferriferous limestone in places partly replaced by carbonate of iron	1-7
No. 2 White, plastic fire clay	3-8
Gannister.	

The following analyses of the clays from this place were made by Robert Peter and furnished W. C. Phalen in Bulletin 349, U. S. Geological Survey, page 116, by the Ashland Fire Brick Company:

	(1)	(2)
Silica	40.14	56.40
Alumina	43.72	28.00
Ferric oxide	1.98	
Lime, Magnesia	1.60	1.30
Water	12.56	14.30

No. 1 is from the upper stratum and No. 2 from the lower stratum given in the above section.

About 40 feet above the top of the above noted section is a thin coal which has been worked for local use. One hundred feet above the Ferriferous limestone in the same hill is a deposit of flint clay which was worked years ago but was abandoned on account of the large percentage of iron it contained.

The Clinton Fire Brick plant is owned and operated by the Ashland Fire Brick Company. It is located a short distance west of the Ashland Coal and Iron Company's Blast Furnace. The clay used at this plant comes from the same sources as that used at the main plant.

The plant uses about twenty-eight tons of flint clay and four tons of calcine a day from the Hayward mine. This is mixed with the No. 2 plastic clay from the Ashland mine as a bond. The output of the plant is 8,000 bricks a day. Only high grade, handmolded bricks are made. They are dried on a hot floor heated from beneath by dry heat generated by the combustion of coal.

The green bricks are laid on the hot floor and dried for about two and a half hours and are then repressed. After repressing they are placed on the floor at the end farthest removed from where the hot air enters the dryer and dried for about three days longer.

The plant is equipped with five round, down-draft kilns with only one stack to the kiln. Three of the kilns have a capacity of 50,000 bricks each; one has a capacity of 60,000 and one of 80,000. Gas is used as fuel for burning the bricks. Eight to nine days are required to burn a kiln of bricks.

The Ferriferous limestone and the accompanying deposit of fire clay continues down the Ohio River from Ashland to near the mouth of Yewlands creek, four miles above Greenup. At the site of the old Amanda Furnace two miles below Ashland, the fire clay has been worked and shipped to Cincinnati and to the Taylor fire brick plant at McCall. The following section of the mine was given by one of the men who worked in the mine:

	Feet	Inches.
Shale to top of the hill.		
Sandstone	....	4
Good coal	....	15-16
Parting	....	1
Coal	....	15
Shale parting	....	4
Coal—good quality	....	8-14
Sandstone	20	
Potters clay	4-9	
Green shale	2	6
Red limestone ore	½-1	
Ferriferous limestone	6-9	
No. 2 plastic fire clay	5-7	
Gannister used at steel plant for lining cupelos	....	18-20
Heavy-bedded sandstone	25-40	

The fire clay associated with the Ferriferous limestone has been opened on the O'Kelly Brick Company's property in east Ashland. The fire clay here is seven feet thick with a thin parting of black bony slate near the center. Mr. O'Kelly expects to use this clay in connection with a fire clay that occurs fifty feet lower just beneath coal number four, which outcrops in the same hill, in the manufacture of fire brick.

WEAVER POTTERY COMPANY.—At the Weaver Pottery Company's plant near Cliffside Park, between Ashland and Catlettsburg, the fire clay at the Ferriferous limestone horizon is being used in the manufacture of jugs, churns and similar wares.

The clay used at this plant rests directly on the Ferriferous limestone. There is an interval of eight feet between the lowest bed of clay that is now being worked to the top of the heavy-bedded sandstone which forms the cliff between Ashland and Catlettsburg. The thickness of the clay varies from four to five feet. The color of the clay varies from dark near the top to a light drab below. A band of bony slate one to two inches in thickness with a thin coal occurs near the top of the clay. Above this is a dark plastic clay the thickness of which was not determined.

Forty feet below the clay opening, at the base of the cliff-forming sandstone, coal number four is now being mined and used at the pottery plant. The coal is three feet thick at this place. Underneath the coal is a deposit of fire clay three feet in thickness. This is the same coal that has been opened on the O'Kelly property in east Ashland.

The plant has one round, down-draft kiln of 4,500 gallons capacity. It requires sixty hours to burn the ware. Coal is used as the fuel.

ECONOMIC PRODUCTS OTHER THAN FIRE CLAYS INCLUDED IN THE AREA OF THIS REPORT.

A number of industries utilizing raw materials found in the area included in this report deserve mention here. In a few instances the raw materials are shipped outside of the district where they are converted into finished products. The economic commodities consist of coals, limestones, shales, asphalt, iron ores, glass sand, sandstone, oil and gas.

COAL.—Workable beds of coal are found in the area east of Little Sandy River, and, to a slight extent west of it. The coals include those from the base of the Coal Measures up to and including coal No. 7. The greater amount of the coals belongs to the bituminous variety. The most promising beds are those found along the

Chesapeake and Ohio Railroad from Denton to Ashland. An excellent variety of cannel coal is mined near Hunnewell, Boghead and Willard.

LIMESTONES.—Brief descriptions have been given of the Mississippian limestone, which is found associated with the fire clays of the Olive Hill district, and the Ferriferous limestone which is found in the Ashland district.

The Ferriferous limestone is mined in the vicinity of Ashland and used as a flux in the blast furnaces at that place. At Ironton, Ohio, it is used with the accompanying fire clay in the manufacture of Portland cement. It is a fairly pure limestone, but at no place in the area is it of sufficient thickness to be profitably mined except as a byproduct of the accompanying fire clay deposit.

A discussion of the area, thickness and extent of the Mississippian limestone has been given under the discussion of the geology of the region.

Quite an industry has developed along the three divisions of the Chesapeake and Ohio Railway of this area in crushing the Mississippian limestone for railroad ballast. The crushed stone is sold f. o. b. cars at the crushers at fifty-five cents a cubic yard. The stone is crushed to pass through a 2¾ inch ring. There are two crushers at Olive Hill, one at Enterprise, one at Lawton, two at Carter and one at Tongs, P. O. A brief description of these plants follows:

CHESAPEAKE STONE COMPANY.—This plant is located at Highland at the mouth of Cory creek, one and one-half miles east of Olive Hill. The crusher is built within a few feet of the Chesapeake and Ohio Railroad. The stone is obtained from the quarry which is located on either side of the railroad. That on the north side is quarried and conveyed to the crusher on the south side through a tunnel under the railroad track. The quarry is equipped with five large and five small Ingersoll Rand steam drills. The rock is blasted out of the quarry by dynamite and conveyed over a narrow gauge railroad to the crusher by means of a small steam engine. The stone is crushed by two Gates' mills, a 7-B and 4-K, which have a combined capacity of 600 cubic yards a day exclusive of the dust.

The vertical face of the quarry measures seventy-two feet. The upper bench, which is eight feet thick, is separated from the main ledge by five feet of green shale

which contains a thin band of limestone three inches thick. The limestone above the bed of green shale is a comparatively pure white limestone which weathers into a very irregular surface. It has the general appearance of the St. Genevieve limestone of Western Kentucky. The upper part of the main ledge is of a bluish color, very hard, and contains numerous round and oblong flint nodules similar to the St. Louis.

The following is an analysis of a sample of the grayish white stone from this quarry made by J. S. McHargue. Sample collected by J. P. Nelson.

Analysis of Air Dried Sample.

	Per cent.
Moisture	.04
Ignition (carbon dioxide, organic matter, etc.)	34.30
Silica	20.06
Alumina and trace of phosphorous pentoxide	4.48
Ferric oxide (equivalent to 4.18% ferrous carbonate)	2.88
Lime (equivalent to 50.00% calcium carbonate)	28.00
Magnesia (equivalent to 21.36% magnesia carbonate)	10.17
Total	99.93

ATLAS STONE COMPANY. This plant is located on the north side of the Chesapeake and Ohio Railroad bridge across Tygart creek one mile east of Olive Hill. The stone is the same as that used at the Chesapeake Stone Company's plant. The thickness of the bed now being worked is about eighty feet. The hill above the quarry has a steep slope and contains only two to four feet of overburden.

The quarry is equipped with three large Ingersoll Sargent and two small, hammer, steam drills. In addition to these they have a six-inch Cyclone steam churn drill, the kind ordinarily used in well-drilling.

The stone is conveyed to the crusher in small cars drawn by mules. The plant is equipped with one No. 8 and two No. 5 Gates' rock crushers. Seven to ten car loads of stone are crushed daily. The crushed stone is sold to the Chesapeake and Ohio Railroad Company for railroad ballast. The following analysis of a sample of stone from this quarry was made in the chemical laboratory of the Survey by J. S. McHargue, Survey Chemist. Sample collected by J. P. Nelson.

Analysis of Air Dried Sample.	Per cent.
Moisture	.05
Ignition (carbon dioxide, organic matter, etc.)	42.15
Silica	1.64
Alumina and trace of phosphorous pentoxide	.38
Ferric oxide	.48
Lime (equivalent to 97.10% calcium carbonate)	54.88
Magnesia (equivalent to 0.67% magnesium carbonate)	.32
Total	99.90

LIMESTONE MINING COMPANY.—The Limestone Mining Company established a stone crusher at Limestone in 1904. They are using the Mississippian limestone for railroad ballast. The limestone is here near the top of the hill. It is broken down with dynamite and loaded into small cars which are run over a seventy-five foot embankment into the crusher.

The stone is crushed in a No. 5 Austin mill, and an Aurora mill No. 2. The daily capacity of the plant is 300 cubic yards of crushed stone.

The following is a section of the quarry:

	Feet.
Overburden	10
Hard blue limestone	13
Pure white, oolitic limestone	10
Thin, stratified stone containing flint nodules	13
Purple, stiff clay	3
White, pure limestone	6
Hard blue ledge with small oval shaped flint nodules	27
Base of Quarry.	

The following is an analysis of the hard, white stone from this quarry. The sample was collected by J. P. Nelson. Analysis made by J. S. McHargue.

Analysis of Sample, Dried at 100° C.	Per cent.
Moisture	.05
Ignition (carbon dioxide, organic matter, etc.)	40.71
Silica	4.94
Alumina and trace of phosphorous pentoxide	1.22
Ferric oxide	.48
Lime (equivalent to 92.50% calcium carbonate)	51.80
Magnesia (equivalent to 1.60% magnesium carbonate)	.76
Total	99.96

LAWTON LIMESTONE COMPANY.—The Lawton Limestone Company of Lawton station, which is located on the Chesapeake and Ohio Railroad three miles west of Limestone, is operating a stone quarry in the Mississippian limestone. A ledge thirty feet in thickness is quarried and the purest part is shipped to the Ashland Iron Works for flux. The refuse is crushed for railroad ballast. The output of the plant is 300 tons a day.

CARTER CRUSHER COMPANY.—About 1 mile up Smith creek from the town of Carter the Carter Crusher Company is working a ninety-foot ledge of Mississippian limestone. The stone is crushed and used as ballast by the Chesapeake and Ohio Railroad Company. The company operates two Gates' crushers, one No. 7½ and one No. 5.

POPULAR BALLAST COMPANY. Two miles above Carter on the south side of Smith creek the Popular Ballast Company of Carter is working a ninety foot ledge of Mississippian limestone. The stone is crushed and used exclusively for railroad ballast. The full thickness of the limestone at this place is 130 feet but the upper 30 feet are partly hidden and perhaps interbedded with shale.

The plant has a capacity of twenty cars of crushed stone a day. The largest daily output has been seventeen cars, with a daily average of fifteen cars.

The base of the limestone is about 125 feet above the track of the Chesapeake and Ohio Railroad. A large No. 7½ Gates' crusher is located at the base of the limestone outcrop. The broken rock from the quarry is conveyed to the crusher in side-swing steel dump cars drawn by a steam engine and dumped directly into the crusher which is constructed at the bottom of a funnel-shaped bin. From the large crusher the broken stone passess by gravitation to a No. 5 rebraker and from here it is conveyed over an endless belt, twenty-four inches wide, to the chute and loaded into the cars. From the time the stone is dumped into the large crusher until it falls into the cars 125 feet below it is assisted by the action of gravitation.

The quarry is equipped with three Ingersoll Rand air compresser drills. It is the intention of the company

to install a six-inch Cyclone well drill which will be used to drill a line of holes parallel to face of the quarry.

The quarry drills are operated by an Ingersoll Rand Automatic air compressor.

WILSON BALLAST COMPANY. In 1910 the Wilson Ballast Company established a crusher plant at Tongs, P. O., eight miles north of Greenup. A section of the quarry was given on another page of this report. The plant was shut down in August, 1912. The limestone that was used for ballast is only thirty feet in thickness, and is overlain by sixty-five feet of sandstone and shale which prevented the limestone being worked at a profit.

The following analysis of a sample of stone from this place was made by J. S. McHargue, the Survey Chemist. Sample collected by A. F. Foerste.

Analysis of Sample, Dried at 100° C.

	Per cent.
Moisture	.18
Ignition (carbon dioxide, organic matter, etc.)	41.30
Silica	7.10
Alumina	1.60
Ferric oxide	2.40
Lime (equivalent to 56.42% calcium carbonate)	31.60
Magnesia (equivalent to 32.52% magnesium carbonate)	16.26
Phosphorous pentoxide	Tr.
Sulphur	Tr.
Alkalies	Tr.
Total	100.44

SHALES.—Very little attention has been paid to the valuable shale deposits of this part of Kentucky. Located as they are in a region of abundant cheap fuel and bordering a large territory to the west where it is impossible to obtain raw material of this kind, there is no reason why the deposits which are located on the railroad lines traversing this region should not be utilized.

The Waverly shales which outcrop in the town and for a distance of one or two miles west of Morehead could be made into sewer pipe, paving brick, English face brick, and perhaps terra cotta, roofing, coping, etc. This same

bed is now being utilized at Indian Run and at Portsmouth, Ohio, in the manufacture of paving brick.

Thick deposits of Coal Measure shales outcrop on the Chesapeake and Ohio Railroad two miles east of Olive Hill, and again in the town of Hitchins.

Paving brick shales are also found in the high bluff facing the Ohio River at Greenup. A plant could be located here near the terminus of the Eastern Kentucky Railroad and on the main line of the Chesapeake & Ohio Railroad. Coal Measure shales are found at intervals between Greenup and Ashland on the Chesapeake & Ohio Railroad, and also along the Eastern Kentucky Railroad from Greenup to Willard.

PORTSMOUTH GRANITE BRICK COMPANY.—Some idea may be obtained as to the value of the shales of this region by a glance into the plant of the Portsmouth Granite Brick Company, located two miles west of South Portsmouth, near the mouth of Indian Run.

The plant was originally equipped as a fire brick plant. The fire clay was obtained on Dry Fork of Schultz Creek, seven miles to the southeast in Greenup County. On account of the poor quality of fire clay used and the expense of getting it to the plant, it was finally sold to the present company and converted into a paving brick plant.

The shales used here are found in abundance right at the plant. They occur in three zones. The lowest zone near the base of the hill is a dark blue unweathered shale which is not used on account of containing too much iron and alkalies.

Above the dark unweathered shales is a semi-weathered zone where much of the impurities have been removed by the leaching action of carbonated waters in the presence of air. In this the sulphide of iron has been converted into the oxide which stains the shales red and brown.

Above this is a zone of still greater weathering where the material has been broken up into a soil. A mixture consisting of fifty-five per cent from the upper zone and forty-five per cent from the middle zone is used in making the pavers.

The plant is equipped with two dry pans for grinding the mixture as it comes from the bank. It is then tempered and pugged in a Fate, stiff mud, side, wire-cut

brick machine. The bricks are repressed in a power press and the name "Granite Block" imprinted on each brick.

The bricks are dried in drying tunnels which are equipped with two large fans. One fan draws the waste heat from the kilns into the dryer and another is used to draw off the moisture from the drying bricks. The bricks remain in the dryer thirty-six hours. The dryer has a capacity of 44,000 bricks. The dry floor originally used for drying fire brick is used as an accessory dryer for the pavers.

There are six round, down-draft kilns, four of which hold 30,000 bricks each, and two hold 43,000 each. There are two square kilns which have a capacity of 30,000 each. It requires eight to nine days to burn a kiln of bricks. Coal is used as fuel.

Asphalt.—About one mile due south of Soldier, on the property of Whitt and King, is an outcrop of asphalt at an elevation of 1,040 feet above sea level. It is a coarse-grained sandstone which is completely saturated with oil. Where exposed to the sun for a day or two the black oil runs out of the rock. An 18-inch seam of coal outcrops just above the asphalt rock on the opposite side of the hill. The following is a section made at the asphalt opening:

	Feet.	Inches.
Gray sandstone.		
Stratified gray clay	....	12
Gray sandstone	....	2
Gray, stratified, plastic clay	....	6
Asphalt rock	4-6	
Gray plastic clay.		

A short distance down the same branch and a few feet below the asphalt horizon, is an outcrop of the Mississippian limestone which lies just below the fire clay.

There is an interesting relation of the asphalt rock to the fire clay of this region. The asphalt rock occupies a geological horizon just above the fire clay. In some places where the fire clay is absent the asphalt may be found below the horizon of the fire clay, or it may be so thoroughly disseminated through the rocks that it has not accumulated to any extent.

The asphalt rock was opened on J. P. Danner's place one-half mile west of Soldier; on J. D. Patton's land across the branch from Danner's; and again on L. S. Vincent's land one quarter of a mile northeast of Soldier.

At Mr. Danner's there is a ledge of sandstone 14 feet thick, the lower 6 feet of which is rich in asphalt. The asphalt rock here rests directly on the fire clay.

About the same conditions exist at Mr. Patton's as are found at the Danner place.

The asphalt at Mr. Vincent's outcrop is found in a stratified sandstone fully 20 feet below the fire clay. Boulders of limestone and fragments of fire clay are present on the opposite side of the hill from where the asphalt is found.

The asphalt is nothing more or less than a sandstone which has become saturated with oil. Were it not for the underlying impervious fire clay the oil in many places would not have collected where it has. In some places the oil found its way into pockets of the clay. At the J. D. Patton clay mine a hole for a shot was made in the top of the clay and the augur struck into a pocket of oil and two or three gallons of thick oil ran down into the mine.

IRON ORES.—Iron ores were extensively mined in this region in the early seventies. A large number of abandoned charcoal furnaces in various parts of the era attest the high esteem in which the iron from this district was held. The ore occurred in irregular packets and was mined in a very crude manner. The furnaces were operated as long as the ore could be obtained in such workings, but on exhaustion of these pockets the expense of mining the ore in a systematic manner was too great and the furnaces were shut down.

GLASS SAND.—A fine grained sandstone which occurs near the base of the Coal Measure rocks is now being mined at Lawton by the Hillman Sand Company, and shipped to Charleston Window Glass Company, the Banner Window Glass Company and the Dunkirk Window Class Company, all of Charleston, West Virginia.

The sandstone ledge used for this purpose is thirty-five feet thick and crushes to fine sharp grains of almost

pure quartz. The output of the plant is about 1,000 tons a month.

SANDSTONE.—In a few localities the fine-grained sandstone which occurs above the heavy-bedded Conglomerate has been used locally for foundation stones, milk houses, and other buildings. It is easily worked when fresh from the quarry and makes a beautiful gray, and very desirable structure. It has no superior as a foundation for bridges and piers, and would make a desirable building stone for dwellings.

A profitable industry could be established at a number of points along the Chesapeake & Ohio Railroad between Soldier and Hitchins in crushing the coarse-grained, loosely cemented Conglomerate sandstone for a building sand. At Cory, Grahn, and Aden the sandstone forms high cliffs along the railroad. Such an industry should be a profitable one in view of the fact that all of the sand used in the central limestone region of Kentucky has to be shipped in.

OIL AND GAS.—Oil and gas wells have been drilled in different parts of this area with varying degrees of success. An oil well was drilled in 1911 on Mr. L. S. Vincent's land one-fourth of a mile north of Soldier. The well was drilled to a depth of 978 feet where a heavy flow of salt water stopped the drilling. The fresh water was cased off at a depth of 230 feet and it was a dry hole to a depth of 950 feet where a light flow of oil was struck. The following is a section of the well made by Mr. Vincent.

	Thickness	Depth.
Gray limestone	530	530
Black shale	410	940
Gray clay containing gas and oil	10	950
Sand, oil and gas-bearing and salt water in bottom	28	978

The salt water rose in the well to within 170 feet of the surface, and oil now stands 75 feet deep on top of the salt water. Gas still flows from the well and burns when ignited with a match.

The well was started fifty feet below the top of the Waverly sandstone, on the eastern flank of an anticline, the north-south crest of which is about one-half mile

to the west. It is possible that a well a short distance to the west nearer the crest of the anticline would strike a larger flow of oil at the same depth.

Wild cat wells have been drilled at Lawton, Cory, Grayson and Denton. The following is a log of Queen Farm Well No. 1, Denton. The well was started 50 feet below Coal No. 7.

	Thickness.	Depth.
Surface	10	10
Blue shale	100	110
Water sand	60	170
Blue shale	320	490
White sand	120	610
Blue shale	15	625
Fire clay	10	635
White lime	125	760
Red clay	10	770
Blue shale	65	835
Big Injun sand	165	1,000
"Hard shell"	40	1,040
Blue shale	205	1,245
"Berea Grit"	90	1,335

The well was completed after the writer's visit to it, but no oil was reported.

An oil well was drilled at Carter on Buffalo Creek in 1902 by some parties from Carter. The following is a log of the well:

	Thickness.	Depth.
Soil	14	14
Freestone	86	100
Blue shale	84	184
Sand—trace of oil and gas	28	212
Gray shale	278	490
Black shale	60	550
Fire clay—white	10	560
Close sand containing gas	40	600
Gray shale	50	650
Black shale	325	975
Fire clay—white	60	1,035

Sand and salt water rose to the surface. When first completed the gas from the well had a pressure of

27 pounds. It now has a 30-pound pressure and is used in Carter for heating and lighting purposes.

The well was started 175 feet below the top of the Waverly.

A number of factories in the town of Ashland are now using natural gas secured from wells in the vicinity of Ashland.

At the Means and Russell Iron Company's brick plant, 1¼ miles west of Ashland at the mouth of Hood's creek, a gas well of 1,710 feet deep was brought in June, 1912. Gas from this well is obtained for drying and burning 1,000,000 bricks a year, and also supplies fuel for the boilers.

The well was started at an elevation of 520 feet above sea level, and 80 feet below the Ferriferous limestone.

CHAPTER VI.

ORIGIN AND NATURE OF CLAY.

There are two distinct viewpoints to be considered in defining clay. From the standpoint of the practical clay worker clay is an earthy substance which when mixed with the proper proportion of water and thoroughly kneaded becomes a plastic mass that remains constant when molded into any desired shape. Thus it is seen that plasticity is primarily the essential economic characteristic of clay. It is one of the principle properties that has made clay one of the most useful natural substances of modern times. There are some highly refractory flint clays and pure kaolins that do not possess the property of plasticity and from this standpoint, therefore, would be excluded from the category of clays. However these non-plastic materials become valuable as clay products when used with some bonding material.

The chemical definition of clay more clearly defines it with reference to its composition without any bearing on its physical properties. Kaolinite, the purest form of clay is a hydrous silicate of alumina. Some white clays, and the flint clays such as are found in Carter County, Kentucky, approach the composition of kaolinite. Most of these, however, are non-plastic and in their natural state, except being refractory, have lit-

tle in common with the plastic clays. Most of the highly flint refractory clays and the kaolins would come within the chemical definition but would be excluded under the term of "an earthy substance that becomes plastic when mixed with a certain amount of water." In like manner most clays that have the quality of plasticity cannot be classed as kaolin. There is a wide range in composition from the purest kaolin to the argillaceous sands.

A definition of clay, therefore, should include the wide range of plasticity, and likewise the extremes in chemical composition. Clay may thus be said to be an earthy substance whose dominant factor is that of plasticity when mixed with water, retains its shape when molded and contains more or less hydrous silicate of alumina.

Kaolinite is the source of plasticity in clays. Plasticity, however, must be regarded as a physicial property and not a chemical one. In its natural state, where it is formed in situ, kaolinite is never plastic. Its plasticity is developed when the mineral is ground to a fine powder and mixed with water. This may take place in nature by being broken up by a running water and carried by the streams and deposited as a reworked product. Where such is the case it is usually mixed with other substnces the mass of which will be plastic in proportion to the amount of kaolinite it contains and also to the fineness of grain.

Kaolinite is a product of the decomposition of feldspar which is found in granites, gneisses and other igneous rocks. Where the feldspathic rocks are exposed at the surface they are attacked by the combined action of air which contains nitric acid, carbon dioxide and moisture, and by acid-laden surface waters. When surface water becomes charged with carbonic acid it forms one of the most destructive agents in decomposing the rocks. It is aided by the action of frost, roots of growing trees and the disrupting forces and strains set up in the rocks by folding, faulting, earthquakes, and other internal dynamic forces. The surface water charged with carbonic acid finds its way into the cracks and crevices of the rocks which gradually yield to the action of these combined agents of destruction. Potash and soda are the first attacked, and the silicates containing these bases

are first to be broken up. The silicates of lime and magnesia are next attacked, then iron silicates, and finally aluminum silicates which are the most indestructible of the compounds.

When feldspar is decomposed the bond which held the rocks together is destroyed and the soluble salts are carried away in solution; leaving behind the silicate of alumina. The amount of quartz and other undecomposed substances carried away by the transported waters will depend on the velocity of the waters and the depth of the decomposition of the rocks. It may thus be seen that the purity of the aluminous minerals in their original state will vary according to the nature of the parent rock and to the mechanical conditions which attend their formation. This process of rock decay is called weathering. The original compounds are thus broken up and new compounds are formed. The breaking up of the old and the formation of the new compounds require untold ages and by this process the various clays as we now find them have been formed.

CLASSIFICATION OF CLAYS AS TO ORIGIN.

From the foregoing discussion it will be seen that clays may be classified as to origin under two general heads, residual clays and transported clays.

RESIDUAL CLAYS.—Residual clays are those that have been formed by the alteration and decomposition of rocks on which they rest. The purest form of residual clay is kaolin. Instances have been found where kaolinization has taken place to a depth of 100 feet, but this is an exceptional case. On steep slopes the clay will be removed as rapidly as formed. Even fragments of the original rock may be carried down the slopes and deposited with the clay mass and later decomposed forming small bodies of pure clay in the less pure mass.

The purity of the residual clay depends on the character of the original rock, and the thoroughness of the decomposition. If the original rock is a compound of feldspar and quartz and the kaolinization has been complete the result is a mixture of kaolin and quartz. In most clays there will be more or less sand, feldspar, mica, iron in some form, and other less important minerals.

Residual clays are also formed from the weathering of limestones, argillaceous shales and some clayey sandstones. In the case of limestones the calcium and the magnesium carbonates and the iron oxides are dissolved out and carried away by the acidulated waters leaving behind the insoluble clay compounds, sand and chert. The bonding materials of sandstones and shales are broken up by the weathering agents, and where conditions are favorable thick deposits of clay may result

TRANSPORTED CLAYS.—By far the largest clay deposits are those which result from the breaking up of residual deposits by running waters and are carried down the slopes and deposited in bodies of still water. The fine particles of clay are the first to be taken up by the running streams leaving behind the heavier particles of sand, undecomposed mica and feldspar. The distance these sediments are carried depends on the grade and the velocity of the stream. A stream having a velocity of one-third of a mile an hour is sufficient to carry the minute particles of clay, but will not affect the sand and heavier particles. A stream with sufficient velocity to carry small fragments of rock will carry a large amount of clay particles. A slight decrease in velocity will result in dropping the heavier materials, and with a complete loss of velocity even the finest particles will settle to the bottom. Each sudden rise of the stream will carry the mass a little farther until it reaches its final resting place where the particles arrange themselves according to their specific gravity. The heavier fragments are dropped near the shore, while the finer particles are often carried far out into the body of water where beds of almost pure clay accumulate.

MARINE CLAYS.—Marine clays are those which have accumulated on the continental shelf or in deep sea water adjacent to some land area. Near the shore, where the waters are likely to be much disturbed and shallow, the deposits will be largely coarse materials. The finer particles of clay will be carried out into deeper, still water. Vast deposits are thus formed, but owing to the fact that some streams traverse a region of igneous rocks, and others come from a region of sedimentary rocks there will be a wide variation in marine deposits. Later beds of an entirely different character may cover

thick, with a good shale roof and the "pink eye" clay at the bottom. The mine was opened about 1904 and some clay shipped to Pittsburg. The clay is said to have been rejected on account of not being carefully selected.

PATTON CLAY MINE.—Mr. J. D. Patton operated a clay mine three-fourths of a mile north and west of Soldier from 1907 to 1912. A spur from the Chesapeake and Ohio Railroad connects the mine with the main line of the railroad. The clay is from 6 to 11 feet thick and has a good shale roof and "pink eye" clay bottom. The clay in this mine consists of about 90 per cent semi-hard and 10 per cent flint. The latter occurs near the center of the vein. That above the flint has a bluish tint and is more plastic than the clay below the flint which is white. The bottom of the clay is uneven and lies in rolls or waves.

The same persistent coal seam which occurs on top of the clay is found in this mine. It varies in thickness from 2 to 4 inches. The shale above the coal is about 10 feet thick.

The clay from this mine was shipped to Woods-Lloyd Company, of Pittsburg; to the Louisville Fire Brick Works, of Louisville; and to the Ohio Valley Clay Pot Company, of Steubenville, Ohio.

HALDEMAN.—In 1903 the Kentucky Fire Brick Company of Portsmouth, Ohio, established a fire brick plant at Haldeman, which is located a few hundred yards west of Triplett tunnel in Rowan County.

The plant is located about 250 yards up a little draw from Haldeman station and is connected by a spur with the Chesapeake and Ohio Railroad. The mouth of the mine is right at the plant and only 30 feet above the grinding room. The clay is brought out of the mine in cars drawn by mules and dumped over the tipple at the grinding shed where the clay is mixed and dried in the same manner as it is done at the Olive Hill plants. The kilns are built on two sides of the drying room. After burning, the bricks are stored in the stock sheds from whence they are loaded directly into the cars for shipment. The plant has 14 kilns with a daily output of 40,000 to 50,000 bricks.

The products of the plant are shipped to Birmingham, Pittsburg, Cleveland and other places to the north and the west.

The mine from which the clay is obtained is located on the south side of the plant. The entry was first driven 240 feet due south, then turned in a southeastern direction and followed under the crest of the ridge for a distance of 1,800 feet with comparatively few side rooms. The mine is still in a state of development.

There is no whim rock and only a small amount of silica rock in this mine. At no place has the silica cut out the clay. The clay has an excellent shale roof 15 feet thick with 5 feet of sandstone above the shale. The mine is comparatively free of water.

The clay will average 6 feet in thickness throughout the mine and varies very little from that amount. The run of the mine, according to Mr. H. K. Leighow, the General Manager, will average 40 per cent of flint, 40 per cent of semi-hard and 20 per cent of plastics.

The following is a section made at the mine:

	Feet	Inches.
Sandstone	5	
Shale	15	
Coal	....	4
Thin layers of shale in some places.		
Plastic clay	....	12-20
Flint clay	....	26-30
Semi-hard clay	....	26-30
"Pink eye clay."		

The "pink eye clay" is known to be 6 feet thick, but has never been penetrated. The limestone was not seen west of Triplett tunnel, but is reported to be very thin in places.

The hill at the plant rises 150 feet above the level of the clay and is one of the highest in this region. At a point about 90 feet above the clay is a ledge of comparatively pure sandstone which is mined by the company, ground and mixed with the plastic clay and burned into a silica brick. It is reported to give good service in coke ovens and other places where it has been used. Here and at the Harbison-Walker plant at Olive Hill are the only two places in the district where the silica bricks are made.

BRINEGAR CLAY MINE.—At the Brinegar clay mine, 3 miles southeast of Haldeman, an opening was driven on the clay for a distance of 1,000 feet in the hill. The clay was about 6 feet thick with 3 feet of flint and the same thickness of semi-hard. The mine was operated for about eight years and was finally abandoned on account of the low price of clay and high freight rates. The flint clay only was shipped. It was hauled to the railroad at Enterprise over a tram road, and shipped to Portsmouth, Ohio.

The heavy bedded conglomerate sandstone is absent in the region about Soldier and Haldeman, but is more than 75 feet thick at Limestone. It thins to the west and on the east side of Triplett tunnel, it is either very thin or entirely gone. No limestone was seen around Haldeman on the west side of the tunnel. It was found near the tops of the hills farther west in the vicinty of Morehead.

ELLIOTTVILLE.—Extensive deposits of fire clay occur in the immediate vicinity of Elliottville on the headwaters of Christy creek and also on the east side of the divide on the headwaters of Tygart, Big Sinking, Little and Big Caney Creeks. The clay of this territory is still undeveloped due to a lack of transportation facilities.

The territory to the north and east of Elliottville has been thoroughly tested by core drill holes and a large percentage of the best clay land bought up by the Harbison-Walker Refractories Company. The results of their work show that the clay deposits are extensive and the quality as good as the best clay found in the vicinity of Olive Hill. Other companies have also acquired considerable clay land in this region. Most of this territory will doubtless remain undeveloped until the clay nearer the railroad has been exhausted. It is only a question of time, however, when this territory will be one of the largest clay producing areas of the Olive Hill district.

The territory east of the north-south divide, from Soldier to Elliottville can be easily reached by a tram road from Enterprise up the South Fork of Tygart creek. The clay from the west side of the divide could be taken out over a tram road up Christy creek from Rodman. In either instance it would require eight to ten miles of tram

road to connect the center of the clay field with the Chesapeake and Ohio Railroad.

In the Elliottville region the Mississippian limestone is generally present. It is about thirty feet thick on the headwaters of Christy Creek. It is also present on the headwaters of Tygart, Big Sinking, Big and Little Caney and Laurel creeks. It is sixty feet thick on Main Caney creek, three miles south of Elliottville.

In the immediate vicinity of Elliottville the Conglomerate is either entirely absent or in very irregular areas. It thickens to the east and south. It is 90 feet thick at the head of Laurel. Three miles northwest of Newfoundland, in Elliott County on Big Caney, it is 180 feet thick with the limestone in the bed of the creek.

The fire clay outcrops in the road in the town of Elliottville a short distance below the postoffice at an elevation above sea level of 1,050 feet. A core drill hole put down by the Harbison-Walker Company on G. L. Maccabee's land about 200 yards east of the outcrop in the road is reported to have shown the following:

	Feet.
Plastic clay	7
No. 1 flint clay	7
Semi-hard clay	2

The Mississippian limestone outcrops in the road just below the fire clay.

A deposit of flint fire clay outcrops on Jesse Bryant's place near the head of Andy White branch. Here the clay is 30 feet above the top of limestone. A ledge of coarse-grained sandstone forms the interval between the limestone and the fire clay. The clay is of a light gray color and apparently free of impurities. The following is a section of the deposit:

	Feet.
No. 1 flint	2½
Semi-hard	2
Plastic—bottom not seen.	

About 300 yards farther down the same branch the fire clay rests directly on the Mississippian limestone.

At an old clay opening on Walker branch two miles below Elliottville the flint clay is seven feet thick. The

clay here contains a large amount of free silica and is of a greenish color due to the presence of iron. The clay is very hard, and on exposure to the elements, does not disintegrate readily. The elevation of the clay on Walker branch is 30 feet higher than it is at Elliottville, giving a southeastward dip of 15 feet to the mile.

The fire clay has been opened on the following places on the headwaters of Christy creek: F. M. Weaver's, A. J. White's, E. S. Hogg's, John Scague's, Jerry Fletcher's, George Bruce's, J. D. Walker's, Emery Bates.'

In the Elliottville territory the fire clay at the top of the limestone is overlain by a thin vein of coal with ten to twelve feet of shale above the coal. Above the shale comes five to ten feet of thinly bedded sandstone with layers of shale between. The No. 4 plastic clay which comes just above the coal is found in some of the openings.

Craney Creek.—The fire clay deposits diminsh in extent and thickness on going southward from Elliottville. The quality of the clay is likewise poorer than to the northeast. The Conglomerate sandstone is very prominent in all of the country from Elliottville to Licking river. A few deposits of fire clay were observed on the headwaters of Craney. Flint clay fragments that have withstood the weathering agents were seen in the road on main Craney about three miles south of Elliottville. Elevation of the clay is 1,040 feet above sea level.

About one mile farther south on the same stream the fire clay horizon is plainly marked on the sides of the hill by a bench at the top of the Mississippian limestone. The clay, where exposed at the surface, is of fair quality, but it has never been developed.

Waggoner Branch.—There is an exposure of the fire clay at an elevation of 1,055 feet above sea level at the head of Hammon's branch, a small tributary to Waggoner branch. The Mississippian limestone here is fifty feet thick with a ten foot bed of lithographic stone between this and the Waverly. At the base of the Conglomerate the fire clay is about ten feet thick; the upper part of the exposure is a hard, bluish flint clay. The elevation of the clay, barometric reading, is 1,055 feet above sea level.

The crest of the ridge between Waggoner branch and Dry Fork, barometric reading, is 1,230 feet above sea level. The Conglomerate here is 80 feet thick. The bed of Waggoner's branch near its mouth is 860 feet above sea level.

MOREHEAD.—The Waverly sandstones and shales form the surface of Rowan County to the north and west of Morehead. East of Triplett creek the Mississippian limestone catches under the tops of the hills and dips to the east and southeast. Triplett creek from the mouth of Dry Fork to Triplett practically marks the northwestern boundary of the Mississippian limestone. The high hill just east of the depot at Morehead shows about 530 feet of Waverly and large blocks of Mississippian limestone.

Near the base of the hills just north and northwest of Morehead is a bed of Waverly shales that are well adapted to the manufacture of paving brick, sewer pipe and fancy English face bricks. The shale deposit is 50 to 75 feet thick and could be mined by steam shovel or by plow and scraper method. A number of locations could be found near the main line of the Chesapeake and Ohio Railroad where a plant could be built with the shale near at hand. Samples of shale from Morton Laim's land, just outside the town of Morehead, were sent to the Olive Hill Fire Brick Company's plant at Olive Hill and made into brick. The bricks made of this shale are reported to have burned to a deep red color with a uniform spotted surface appearance due to the presence of iron in the form of pyrite.

The same shale horizon is continuous from Mr. Laim's house through Mr. F. C. Nickell's land to the Chesapeake and Ohio Railroad at Brady switch, one mile west of Morehead.

The most extreme southwestern point where the fire clay is known to have been worked is on Mr. Sam Bradley's land, three miles south of Morehead near the head of Morgan branch. The flint fire clay occurs forty feet below the crest of a high hill just west of the Morehead and North Fork railroad. The elevation of the top of the hill is 1,280 feet above sea level. Elevation of the clay horizon is 1,240 feet. The base of the Mississippian

limestone at this place is 1,100 feet above sea level. The clay occurs up in the Conglomerate, perhaps 40 feet or more above the top of the Mississippian limestone.

About sixteen years ago the fire clay was mined at this place by Mr. William Cooper and several car loads shipped. The clay was hauled by wagons to Brady's switch, on the Chesapeake and Ohio Railroad, one mile west of Morehead. The clay is reported to be five feet thick. The work was abandoned on account of the expense of hauling.

YOCUM CREEK.—Yocum creek is a stream about three miles long which enters North Fork of Licking River from the south, opposite Paragon. It has cut its bed through the heavy bedded Conglomerate sandstone and the Mississippian limestone and exposed the upper strata of the Waverly for a distance of about two miles up the stream.

The flint fire clay has been opened at two or three places on this stream. On Hog Camp branch, about three-fourths of a mile from the head of Yocum, a good quality of fire clay was opened in 1911. The thickness was reported to be nine feet.

A short distance above the mouth of Hog Camp branch on main Yocum, the fire clay is wanting. The following is a section of the contact between the Conglomerate and the Mississippian limestone at this place:

	Feet	Inches.
Conglomerate.		
Thin band of blue limestone	....	4
Calcareous black shale	5	
Mississippian limestone.		

NORTH FORK OF LICKING RIVER.—In the district along North Fork between the mouth of Yocum and the mouth of Devil's Fork, the fire clay is either wanting or is of such a poor quality that it is worthless. The country is very rugged with high precipitous cliffs bordering the streams. The streams all show very rapid down-cutting with practically no valleys. A large per cent of the work of the streams of this region has been employed in cutting through the Conglomerate sandstone which is from 125 to 175 feet in thickness. The Mississippian limestone

is from 25 to 40 feet thick. The southeastward dip of the strata carries the limestone below drainage on North Fork near the mouth of Devil's Fork.

Vigorous prospecting for fire clay has recently been done on North Fork, Bucket creek, Minor, Pretty branch, and Craney creek. Most of these openings were visited by the writer and while the fire clay was seen at only one place, the following notes will show the nature of the contact between the limestone and the Conglomerate. This region was doubtless near the edge of the basin which extended from here to the Ohio river and beyond when the fire clay was forming. The regularity of the Mississippian limestone in the southwestern part of the fire clay area indicates that there was less erosion interval between the deposition of the limestone and the Conglomerate than was the case in the central district. The thickest and best fire clay deposits of the Olive Hill district are found where there is evidence of the greatest time interval and erosion beween the deposition of the Mississippian limestone and the Conglomerate.

LIMEKILN POINT.—The base of the Mississippian limestone occurs in the railroad cut at Limekiln Point. Six feet of the Waverly sandstone are exposed in the lower part of the cut, separated from the Mississippian limestone at this point by a bed of blue shale six feet in thickness. The contact between the two formations is very similar to that found at Deep Cut on the Carter-Lewis County line mentioned in this report.

BOOKER BRANCH.—While in the district the writer was shown a number of samples of lithographic stone said to have come from Elliott and Rowan Counties. At the mouth of Booker branch there is a bed of lithographic stone ten feet in thickness. It is of Mississippian age and lies just above the six foot bed of blue shale which comes between the limestone and the Waverly. The limestone above the lithographic stone is very hard and studded with flint nodules. The lithographic stone was tested and found too soft and porous for lithographic work.

A short distance up stream from the mouth of Booker branch an opening was made for the fire clay at the contact between the Conglomerate and the underlying limestone. A bed of green shale occupies the interval between the two formations.

BUCKET BRANCH.—Two openings have been made at the fire clay horizon on Bucket. One is on the right and the other on the left fork facing up stream. The opening on the right fork is of a dark blue color and contains a large amount of sand.

The opening made on the left fork shows the best fire clay found in this region. The following is a section of the opening:

	Feet.
Conglomerate sandstone.	
Coal	1½
Siliceous claystone and black plastic clay	5
Coal	1½
White to gray boulder flint clay	4
Semi-hard clay	2
Siliceous fire clay	3

DEVIL'S FORK.—At the mouth of the Devil's Fork an opening was made at the contact between the Conglomerate and the Mississippian limestone. Ten to twelve feet of blue fosiliferous shale with a twelve-inch band of hard limestone form the interval between the two formations. The unconformity here is between the blue shale and the Conglomerate sandstone. The limestone disappears below drainage on North Fork a short distance above the mouth of Devil's Fork.

The strata between the mouth of Devil's Fork and Pretty branch have a strong dip down stream or to the north west. The general dip of the strata in this region is to the southeast, but the reverse dip between the two points mentioned is very pronounced.

PRETTY BRANCH.—About one-fourth of a mile up Pretty branch the fire clay was recently uncovered. The base of the Conglomerate was not shown in the opening, but about five feet below the Conglomerate, a bed of greenish flint was encountered. At the surface it is somewhat more siliceous than the gray flint clay, but further development may show a better grade of clay. An eight foot bed of blue shale was uncovered below the fire clay. Bands of red shale six inches thick are found interbedded in the blue shale.

CORY STATION (MCGLONE P. O.).—The fire clay and the Mississippian limestone outcrop along the upper

waters of Gorman Fork to within one-third of a mile of Cory. About one and one-fourth of a mile east of Cory, on Nolan branch, on Mr. J. P. Whitt and Sons' land, is a deposit of fire clay which was opened about 1904. An opening was made 25 feet into the hill and shows five feet of flint clay. The Conglomerate sandstone forms the roof of the clay. The thickness of the clay and its accessibility to transportation would justify a thorough investigation. The samples taken were from near the crop and are not representative of what may be expected farther under the hill. The clay is well above drainage and has plenty of covering above it.

GRAHN.—The clay mines in the vicinity of Grahn were among the first opened in the Olive Hill district. They are owned and operated by the Louisville Fire Brick Works, of Louisville. The mine now operated is located on the north side of Grassy Fork, one-fourth of a mile up the stream from Grahn Station.

The Mississippian limestone outcrops on the south side of Grassv and extends a short distance above the clay mine. It can be traced more or less continuously from a point a short distance below Cory station on Gorman Fork to near the mouth of Dry Fork below Aden. It also extends about two miles up Dry Fork.

The Conglomerate sandstone is not found on the lower waters of Cory Creek on the west side of the divide between the waters of Tygart creek and Gorman Fork. On the waters of the latter stream it extends unbroken to about one mile east of Leon where the eastward dip carried it below the surface. In the vicinty of Grahn it is about 70 feet in thickness.

Near the entrance of the clay mine at Grahn the Conglomerate rests directly on the fire clay. Farther in the hill the bed of shale with the thin coal at the base comes between the clay and the Conglomerate sandstone. The clay is of a poorer quality where the sandstone forms the roof of the clay. In such places there is a large amount of iron in the clay which burns to a red or black color. The shale where it forms the roof of the clay, protects the clay from the iron-bearing waters which filter through the Conglomerate.

The bottom of fire clay is very uneven due to the irregular surface of the limestone on which the clay was formed. In places there are funnel-shaped depressions, wide at the top and tapering to a point at the bottom, very similar in shape to the sink holes so common in some of the limestone regions of western Kentucky. This is the only place in the district where such depressions were found. In some of these depressions the clay thickens to twice its normal thickness. In other places the limestone lumps up and almost cuts out the clay. In no place, however, has the clay been entirely cut out. This irregularity in the bottom of the clay occurs in the southwestern part of the mine. In the northeast portion the limestone has given no trouble. The shale roof is softer here than in the southwestern part of the mine, but the quality of the clay is better.

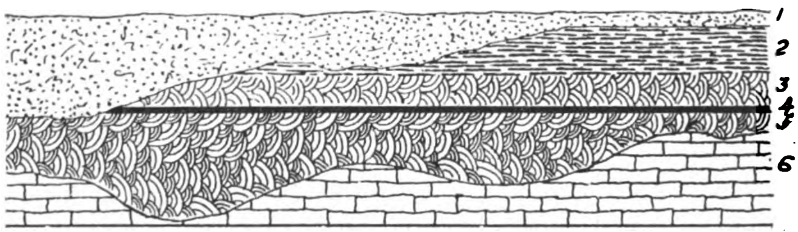


Fig. 5.

Section of Louisville Fire Brick Work's Mine, Grahn, Ky.

1. Sandstone.
2. Shale.
3. Plastic Clay.
4. Coal.
5. Plastic Clay.
6. Limestone.

On coming east the little coal which was one to two inches thick at Olive Hill has thickened to eight inches in the mines at Grahn.

Four grades of clay are found in the same bed here. The No. 1 flint clay varies in thickness from a knife edge to 9 feet. In places the flint is entirely replaced by the No. 2 clay. The latter is a white plastic clay which is the most uniform of any clay found in the mine. However, it varies from 2 to 6 feet in thickness, and in a few places it is entirely absent. Number 3 clay is a red plastic clay

which lies beneath the No. 2 and varies from 1 to 4 feet in thickness. Number 4 is a gray to dark plastic clay which comes above the coal. It is mined and used with the other clays. It varies in thickness from 0 to 5 feet. It is the most irregular of any of the clays.

The average thickness of all of the clays is 6 feet. Where No. 1 is thick the others are thin. Where one clay thickens the others thin correspondingly.

The company is now erecting a 7-kiln fire brick plant at the junction of Grassy and Gorman Fork a short distance above Grahn station, to be known as the Grahn Fire Brick Works. A spur from the Chesapeake and Ohio Railroad is built from the station to the tipple at the mouth of the mines. The kilns are built on the north side of the plant beside the spur and the bricks from the kilns can be loaded directly into the cars. The plant will be equipped with one dry pan, two wet pans, and one brick machine. The daily capacity will be 32,000.

The fire clay horizon extends eastward from Grahn to Aden. The Conglomerate above and the limestone below the fire clay may be seen more or less continuously between these places. Between Grahn and Aden the Chesapeake and Ohio Railroad Company has cut a tunnel through a small projection of the hill at the level of the fire clay. The following is a section at the tunnel:

	Feet.
Rotten shale	7
Coal	1
Fire clay of poor quality	11
Iron ore	1¼
Flinty limestone in beds six inches to three feet in thickness	8

ADEN.—The fire clay was worked at Aden for about 20 years, but the work was shut down at the time of writer's visit. The clay was shipped principally to the Louisville Fire Brick Works, of Louisville.

The mine was opened under the heavy-bedded Conglomerate sandstone which forms a high cliff at Aden. The thickness of the clay varies from 3 to 7 feet with a general average of 4½ feet. The roof of the mine is shale with the thin coal below. In places, however, there

is a dark plastic clay which comes above the coal. It is refractory and was mined and used with the other clays.

Where this is present there is a corresponding thinning of the shale.

The coal at the top of the clay in the Aden mine has thickened to 26 inches and has a shale parting one or two inches in thickness.

Mr. Saulsbury, the owner of the mine, reports that about one-tenth of the clay of this mine was flint and the remainder plastic.

PRATER OPENING.

Two miles north of Aden on Dry Fork an opening was made on the fire clay on the Prater land. The entry was driven 180 feet into the hill. The coal here is two feet thick and was used locally for fuel. The following section was made at the opening:

	Feet.
Shale roof.	
No. 4 fire clay	2
Coal	2
Flint clay	2
Semi-hard clay	2
Pink eye clay.	

MADDIX CLAY.—On Mr. P. F. Maddix's land on the north side of Big Sinking creek, near the mouth of Maddix branch, is an exposure of fire clay which is 20 to 25 feet thick from the top of the coal. Fragments of the flint clay have rolled down the hill, but it is not possible to determine the thickness of the flint.

About one mile south of Aden, near the ford across Big Sinking, Mr. Maddix drove a twenty-yard entry on the fire clay. The clay was found to be 8 feet thick with 15 to 24 inches of flint clay. The coal here is 16 inches thick. The Conglomerate sandstone forms the roof of the mine.

Farther up the creek Mr. Maddix worked the clay for a short time. An extra fine quality of white flint clay was obtained at this old pit.

The most eastward extension of the fire clay and Mississippian limestone found on Big Sinking was found

on the south side of the stream just above the mouth of Halls branch. The top of the limestone is here near the water's edge. It is reported, however, that the clay and limestone occur on Mr. Ike Isom's land, 1/4 mile below the mouth of Hall's branch.

A number of openings have been made on the fire clay on Big Sinking to the south and southeast of Olive Hill. The region is so inaccessible, however, that the clay can never be utilized without a railroad up that stream. The clay where seen by the writer, is of good quality, and the deposits are sufficiently thick to be profitably mined if there was any means of getting it to market.

A road leading south from Olive Hill to Big Sinking up Ben's Run crosses a high divide which is 405 feet above low water in Big Sinking at Joseph Field's house below the mouth of Spruce branch.

The clay has been opened on Joseph Field's place at an elevation of 800 feet above sea level. Flint clay was found on the old clay dump, but the thickness of the bed could not be determined.

The following instructive section was made along the road from Joseph Field's house on Big Sinking to the top of the divide near the head waters of Ben's Run. The elevations given were determined by the barometer and are subject to change.

1115 A. T.	Top of highest hill.
	Shale.
1080 A. T.	Coal bloom.
	Shale.
1045 A. T.	Thin bed of sandstone.
	Shale.
1040 A. T.	Coal bloom.
	Shale.
1010 A. T.	Four-foot vein of coal which is now being worked.
	Shale.
990 A. T.	Thin coal.
	Shale interval.
985 A. T.	Thin bedded sandstone interval.
920 A. T.	Top of Conglomerate sandstone.
	Conglomerate sandstone interval forming steep cliffs.
800 A. T.	Base of Conglomerate and fire clay horizon.
	Heavy bedded limestone interval.
710 A. T.	Bed of creek in Big Sinking.

A 5-foot bed of fire clay is reported to have been opened on Jno. Baker's land near the mouth of Dudley branch. A number of other openings of fire clay have been made in this region of Big Sinking but the writer did not see them.

BARRETT'S CREEK.—Barrett's creek rises within two miles of Tygart creek, flows in a general easterly direction and empties into little Sandy river about one and one half miles below Grayson.

In its upper course the stream has cut through about 350 feet of Coal Measure rocks and exposed the top of the Mississippian limestone for a distance of about two miles on main Barrett above the mouth of Smith branch, and for about the same distance on the latter stream.

The flint clay has been opened on main Barrett a short distance above Bull's Eye spring. A heavy bed of shale forms the roof of the clay. The Conglomerate is not exposed in the region where the limestone occurs. The elevation of the clay, barometric reading, is 750 feet above sea level.

The crest of the divide between Barrett creek and Tygart creek is 1,100 feet above sea level.

On the west side of the divide the Conglomerate forms precipitous cliffs along Tygart creek 85 to 100 feet high.

The Mississippian limestone on Tygart at the mouth of Smoky Fork is 75 feet thick. It thickens on Cave branch to 110 feet. About 60 feet of Waverly are exposed at this place.

CAVE BRANCH.—About one-half mile up Cave branch on the south side of the stream the Conglomerate sandstone rests directly on the limestone without any fire clay, shale or iron ore between.

SUTTON BRANCH.—Two miles up Sutton from its mouth the fire clay occurs on Mr. N. F. Burris' land at an elevation of 940 feet above sea level. A short distance above this, on Mr. James McGuire's land, the fire clay outcrops in a number of places. At an exposure on the west side of the road just above his house the clay is 13 feet thick with five feet of flint of good quality and the remainder is a yellowish plastic clay, and "pink eye" at

the base. At the base of the pink eye is a five-inch bed of carbonate of iron.

The Conglomerate and the limestone are both prominent on Sutton. The Waverly extends up the stream from its mouth for a distance of only two miles.

BUFFALO FORK.—On Mr. Joseph Pence's land, one mile east of Carter on a branch of Buffalo Fork, the flint fire clay has been opened showing the following:

	Feet.
Conglomerate to top of hill.	
Covered	8
Flint clay of oolitic structure	4
Impure sandy flint	1½
"Pink eye" clay.	

The elevation of the Pence opening is 1,030 feet above sea level. This opening was made on the south side of the hill. An old opening was formerly made on the east side of the same hill below the Conglomerate. At the extreme north end of the hill facing Buffalo Fork, the clay has recently been opened by some parties from Carter County. It was found at two horizons, one at the base of the Conglomerate and the other about twenty feet above in the Conglomerate. Weathered fragments of flint clay were found around the east side of the hill twenty to thirty feet above the base of the Conglomerate.

DEEP CUT.—The elevation of the crest of the ridge between the waters of Kinniconick and those of Smith's Creek is 1,300 feet above sea level, barometric reading. The Chesapeake and Ohio Railroad crosses the divide at this point through what is known as Deep Cut. About twenty-eight feet of Waverly are exposed. The Mississippian limestone is eighty feet thick with a ten-foot bed of red shale between the two formations. The elevation of the top of the limestone is 1,240 feet above sea level.

CARVER CLAY PIT.—At a point on the road one-half mile south of Deep Cut at an elevation of 1,240 feet above sea level is an old clay pit which is known as the Carver clay pit. It was worked about twelve years ago by Mr. William Cooper and the clay shipped to Covington, Ashland and Huntington. The clay is all of the flint variety.

Some of it is of an oolitic structure; some is red and some a clear white with a dense smooth texture.

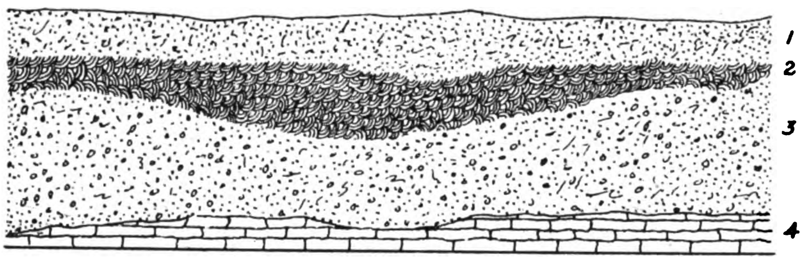


Fig. 6.

Section at Carver Clay Pit, showing Conglomerate under Flint Clay.

1. Sandstone.
2. Flint Fire Clay.
3. Conglomerate.
4. Limestone.

On the west side of the road, and less than 100 yards from the old clay pit, the Conglomerate forms a bold cliff, which is forty feet high. The relation of the clay to the Conglomerate is shown in the following section:

	Elevation Above Tide.
Carver Clay pit	1240
Top of Conglomerate sandstone	1220
Top of Mississippian limestone	1180

There is a pronounced southward dip of the rocks as shown along the road from Deep Cut to the Carver Clay pit. No clay of any consequence was observed between the Mississippian limestone and the Conglomerate at Deep Cut or at the Carver pit.

RILEY CLAY OPENING.—About one mile west of the Carver clay pit on the west side of the road, the flint fire clay has been opened. According to the barometer the elevation of the clay at the latter place is ten feet lower than it is at the Carver pit. The clay occurs beneath a three-foot ledge of sandstone, the lowest two inches of which is brecciated with angular fragments of flint clay. The clay deposit is six feet thick and all flint except eight inches of plastic next to the sandstone roof.

"OLD AIR FURNACE."—The limestone is present along the county line on the headwaters of Brushy creek at an elevation of 1240 feet above sea level. The highest hills rise about 60 feet higher. The flint fire clay was said to have been mined at "Old Air Furnace," on the county line at the head of Brushy, and used at Boone Furnace Works for lining the furnace. An old pit with fragments of flint fire clay on the dump marks the location of "Old Air Furnace." The clay is very dense and resistent to the weathering agents. It is oolitic in structure. Limestone outcrops on the hillside twenty feet below.

GRASSY CREEK.—A deposit of flint clay has been opened on the north side of Grassy creek, about one mile from Boone Furnace. The clay has been uncovered to a depth of fourteen feet with no trace of plastic clay above or below. It is a white clay of a dense, smooth structure with apparently no iron or other impurities. On exposure to the elements it weathers into small rectangular blocks. The deposit is near the top of the ridge. The Mississippian limestone is present on the opposite side of the hill twenty to thirty feet below the flint clay. The elevation of the clay opening is 1,160 feet above sea level.

The following is a section of the strata at the head of Grassy Creek made by A. R. Crandall in the report on the Geology of Greenup, Carter and Boyd Counties, Kentucky Geological Survey. Section 6, plate No. 3:

		Feet.	
Top of Hill.			
Coarse sandstone	about	20	40 feet
Fire clay	about	7	
Dark shale	about	5	
Sandstone	about	5	
Limestone ore	about	3	
Sub Carboniferous limestone		90	
Waverly.			

The following analyses show the quality of the clays from this region:

	No. 1	No. 2	No. 3	No. 4
Silica	45.96	45.56	54.62	48.56
Alumina	38.53	43.77	32.46	37 47
Oxide of iron	Tr.	Tr.	Tr.	Tr.

Lime	.14	.14	Tr.	.11
Magnesia	Tr.	Tr.	Tr.	Tr.
Phosphoric acid	Tr.	Tr.	Tr.	Tr.
Potash	.25	.96	.21	.28
Soda	.34	.72	.67	.28
Loss on ignition	14.21	8.52	11.78	13.03

Analyses from Kentucky Geological Survey Reports.

The flint clay is reported to be present on both sides of Three Prong Creek and also on the waters of Leatherwood creek.

A fourteen-foot deposit of flint clay is reported on the south side of Lost creek near Tygart creek about one mile west of She Bear creek.

ZORNES BRANCH.—Near the mouth of Zornes branch the fire clay outcrops in the road on Garrette Zornes' place. The outcrop here shows about twelve feet of flint clay. Here as at the other localities in northern Carter County the clay is up in the Conglomerate and not at the contact between the Conglomerate and the Mississippian limestone. The Conglomerate forms a cliff around the hill below the fire clay and is also present above the clay. The clay has never been opened and its quality cannot be determined by the surface exposure.

ROCK SPRING CREEK.—A bed of flint clay has been opened on Mr. W. F. Partee's land on the west side of Rock Spring creek, about one mile south of the mouth of Zornes' branch. Two openings have been made on the fire clay at this place. The lower one is at the top of the Mississippian limestone horizon at an elevation of 925 feet above sea level, and the other up in the Conglomerate twenty-five feet higher. The upper one is a hard, impure flint clay of a greenish cloudy effect. The green color is due to the presence of ferrous iron and vegetable matter. The lower clay is of a gray color.

IRON HILL.—A deposit of flint clay outcrops on the east side of the road on Clark branch about one mile north of Iron Hill. The Mississippian limestone is absent here and the clay rests directly on the Waverly. However, the limestone is present farther down the branch. The following section was made of the outcrop. Elevation of the clay 875 feet above sea level.

	Feet.
Flint clay	2
Red shale	2
Blue shale	5
Thin bedded sandstone and shale to bed of branch.	

The flint fire clay has been uncovered on Mr. William Newman's land on Stump's Run three-fourths of a mile east of Iron Hill. The elevation of the clay at this place is 825 feet above sea level, or 115 feet above the bed of Tygart creek at Iron Hill bridge. The following is a section of the opening:

	Feet.
Iron ore	½
Plastic clay	3
Boulder flint clay	5
Pink eye.	

EVERMAN'S CREEK.—Everman's creek, like Barrett's creek to the south, has cut through the Coal Measure rocks and exposed the Mississippian limestone for about three miles of its course. A small fold brings up the limestone within about one mile of the headwaters of the stream. It outcrops on main Everman and for about one mile up Stewart branch. It continues down the main stream for about three-fourths of a mile below the mouth of Stewart branch and then dips under the level of the creek. It appears again farther down the stream a short distance above Wolf Pen branch and continues to near the mouth of the Right Fork of Everman.

A deposit of flint clay has been opened on the north side of Everman's creek about one mile above the mouth of Stewart branch. The clay is about four feet thick and is overlain by ten feet of black shale. The quality of the clay is poor due to the amount of iron contained in it.

At Adkins Post Office, near the mouth of Stewart branch, the clay occurs in the form of a very hard flint of a cloudy blue color known as "calico clay." On exposure to the weathering agents it does not disintegrate like the pure No. 1 flint. It forms a small fall in the branch in front of the Post Office where the clay is six feet thick. The upper part of the deposit is of an amorphous struc-

ture similar to the other deposits of the district: the center and the lower portions are in stratified layers.

The stratified portion of this deposit has a structure that was not observed in any other deposit in the territory. It consists of a series of parallel joints which extend in a northeast and southwest direction with another set at right angles to the first.

It will be seen from the description of the clays of northern Carter County that the deposits are numerous and in many places of great thickness, but the quality of the clay is not as uniform as it is in the territory around Olive Hill and in the southwestern part of the county. Some of the analyses of the clays from the Boone Furnace territory show the clay to be of exceptional purity. In most of the other localities, however, the blue or greenish clay is present in greater or less quantities. It is practically worthless on account of the great amount of iron it contains.

OLDTOWN CREEK.—A bed of flint fire clay is reported to overlie the Mississippian limestone near the headwaters of North Fork of Oldtown creek in Greenup county.

COAL BRANCH.—Coal branch is a small stream that rises within a mile of Tygart creek, flows due east and empties into the Ohio river one mile above Greenup. The Waverly outcrops on the hillsides and in the bed of the stream for about three miles up the creek. The Mississippian limestone was not observed on Coal branch or any of the streams entering the Ohio from Greenup north to Tongs. North of Tongs it forms a thin band in the hills around the point between the Ohio and Tygart creek. West of Tygart creek in Greenup County, the limestone is present on all of the streams south of Big White Oak creek. From here to the Ohio river it is found only on the headwaters of the largest streams.

However, in all of the territory of Greenup County where the Waverly is present there is a considerable amount of siliceous flint covering the hillsides below the base of the Coal Measure rocks. The limestone was evidently deposited over this territory and subsequently eroded before the deposition of the Coal Measure rocks. The flint contained in the limestone was less easily de-

composed by the weathering agents and was left behind as the remnant of the former great mass.

A number of fire clay openings have been made on Coal branch. The clay is of Coal Measure age as it occurs in shales and sandstones above the top of the Waverly. In most places there is a bed of coal below the fire clay.

The clay contains a considerable amount of free silica, and iron, the latter giving it a greenish color. The clay is of a brecciated nature containing angular fragments of flint in the clay matrix, similar to the clay deposits found up in the Conglomerate in northern Carter.

BIG WHITE OAK.—Flint clay is present on Tygart creek opposite the mouth of Big White Oak at an elevation of 190 feet above low water in Tygart creek. The thickness of the clay was not determined. The clay horizon is marked on the hillside by a pronounced bench which is near the top of the Waverly.

Three miles up Big White Oak on Mr. J. W. Thompson's land near Truitt P. O., the fire clay outcrops at an elevation of 200 feet above the stream. The clay is about six feet thick. The bottom of the clay is highly siliceous and of poor quality.

The Harbison-Walker company have opened the clay on the headwaters of Big White Oak near the site of the Old Kenton Furnace where it is reported to be of better quality but is inaccessible at the present time.

MCCALL.—Charles Taylor's Sons of Cincinnati have a fire brick plant at McCall on the main line of the Chesapeake and Ohio Railroad near the mouth of Tygart creek, two miles above South Portsmouth.

The clay used at this plant is obtained on the south side of Schultz creek six miles south of the plant. The clay is conveyed from the mine to the plant over a narrow gauge railroad in cars drawn by a small engine.

The mouth of the mine is 245 feet above the bed of Schultz creek and 100 feet below the top of the hill. There is a strong eastward dip in the mine of eight feet in sixty. The eastward dip continues for only a short distance where there is a reverse dip.

The clay from this mine is of an inferior quality to that found in the vicinity of Olive Hill. The flint clay

contains free silica and there is so much iron in it that the bricks made of it are spotted and off color generally. Many of the bricks burn dark. The following is a section at the mine:

	Feet	Inches.
Coarse grained sandstone to top of hill	100	
Shale	8	
Coal	....	2-6
No. 2 plastic of a dark blue color	3	
No. 1 flint	5	6
"Pink eye" clay.		

The hillsides below the mouth of the mine are covered with angular fragments of flint, but no limestone was observed.

The brick plant at McCall has seven rectangular, down-draft kilns of 60,000 capacity each and one round, down-draft kiln of 30,000 capacity. The daily output of the plant is 20,000 bricks. There are two wet mud pans and one dry pan. The clay is first ground in the dry pan and then conveyed by an endless belt to the wet mud pans where it is mixed with water and pugged for twenty minutes into a stiff mud. The bricks are all molded by hand. One man molds 4,600 standard sized bricks a day. The bricks are dried on a cement floor heated from beneath. It requires about seven days for burning a kiln of bricks.

The calcine, the No. 2 plastic and the best grade of flint used at this plant come from Olive Hill. These are mixed with the clay from Schultz creek. A very desirable brick is made of seventy parts of No. 1 flint, nine parts of No. 2 plastic and six parts of calcine.

DRY RUN.—The flint fire clay was formerly mined on the east side of Tygart creek opposite the mouth of Dry Run and also on the west side of Tygart between Dry Run and Plum creek. The clay was hauled to the Ohio river at Edgington and shipped to the Adams Fire Brick Plant at Portsmouth.

ROCKY BRANCH.—About eight years ago Messrs. Edgington, Lou Art and J. Johnson opened a clay mine on the south side of Rocky Branch facing the Ohio river. Two kilns were built here and the clay was calcined and shipped to Steubenville and to Pittsburg for glass-pot making. The opening was driven 180 feet into the hill.

The clay is six feet thick at the old opening and is said to be of good quality. It occurs beneath a good shale roof with a 14-inch seam of coal between the clay and the shale. The mine was operated for two years and then abandoned.

LIMEVILLE (TONGS P. O.).—The Mississippian limestone is present in the high hill facing the Ohio river just back of Limeville. The flint fire clay horizon here is composed of a thin bed of green shale, which is apparently refractory. The heavy bedded limestone has been recently utilized by the Wilson Ballast company for making railroad ballast. The following section was made at the crusher:

	Feet.
Beds of siliceous shale interbedded with ledges of coarse-grained sandstone	65
Hard siliceous brecciated sandstone containing plant remains	5
Irregular wavy bed of green siliceous shale weathering in places to a deep red color. Iron ore is found imbedded in the shale. There is a marked unconformity between this horizon and the one below	2-5
Mississippian limestone	30
Waverly to bottom of the hill	280

ASHLAND DISTRICT.

The Ashland district, as previously stated, includes the fire clay deposits associated with the coal seams which occur in the area included in this report. The lower part of the coal measure rocks overlie the fire clays of the Olive Hill district, but the fire clays of economic importance of the Ashland district occupy a well defined area, the western limit of which is from four to ten miles east of the most eastern outcrops of the Olive Hill fire clay.

The most important fire clay deposit of the Ashland district is that associated with the Ferriferous limestone. The outcrops of the limestone and the clay occur in the hills a short distance east of Little Sandy river from the Elliott county line to the Ohio river. The area increases in width from about two miles in the southern part to about fourteen miles in the northern part. The clay is found in all the high hills facing the Ohio river from the

mouth of the Big Sandy to near the mouth of Yewlands creek, four miles above Greenup. The rise of the strata to the northwest carries it beyond the tops of the hills west of Little Sandy river.

Southeast of the area described the dip carries the fire clay below drainage level. The clay is found in well borings at increasing depths as the distance from the surface outcrop increases.

The fire clay deposits of this district are finely comminuted sediments which have reached their present position through the agency of water. They occur as horizontal beds and usually form the floor of coal seams.

There are three grades of fire clay found in the Ashland district. These are: the No. 1 plastic, the No. 2 plastic, and the flint. The latter occurs in thin bands through some of the plastic beds, and composes a very small per centage of the whole.

There are three areas of the Ashland district where the fire clay has been worked. These are at Willard, near the southern border; at Hitchins and Denton, near the center; and at Ashland and Catlettsburg, on the Ohio river. A description of the mines and the fire brick plants of the district will be given in detail.

WILLARD.—The Ferriferous limestone outcrops on either side of Little Fork in the town of Willard. Resting directly on the limestone is a bed of plastic fire clay which has been mined in two places in the town of Willard.

At the northern edge of town Dr. H. B. Fraley opened a mine on the fire clay and operated it for some time, but had to abandon it on account of excessive freight rates and the low price of clay. The mine was located on the east side and about twenty feet above the track of the Eastern Kentucky Railroad. The clay was drawn out of the mine in small cars and loaded directly into the cars from a tipple.

The clay is reported to be of good quality and is a valuable clay when used with flint clay and calcine. It is a highly plastic variety and has a high shrinkage when used alone.

At the eastern edge of Willard the Willard Fire Clay Company opened and operated a clay mine at the same

geological horizon as the Fraley mine. Clay was shipped from here for some time, but excessive freight rates and the low price of clay made the work unprofitable.

The mine was worked by drift. At the mouth of the mine, which is now closed, the clay is five feet thick. At the surface the clay was slightly stained with ferric oxide, but farther in it is reported to be of a light gray to bluish color. The lower third of the bed is of lighter color and harder than the upper two-thirds. A thin seam of coal is reported near the top of the clay.

Just below the Ferriferous limestone in the western edge of Willard, at the foot-bridge across Little Fork, is a deposit of black shale eight to ten feet in thickness. At the base of the shale is a thin coal which rests directly on heavy bedded sandstone. Near the top of the shale is a thin deposit of plastic fire clay with a band of flint clay between the plastic clay and the limestone. The shale and fire clay below the limestone would make an excellent material for sewer pipe. Samples of the raw clay and the shale have been tested for this purpose with good results. Could satisfactory freight rates over the Eastern Kentucky Railroad to Hitchins be obtained, this would be a desirable location for the erection of a sewer pipe or paving brick plant. Fuel for such a plant could be obtained at a minimum cost from coal mines which are now being operated in this locality.

The following analysis of the fire clay from Willard is given on page 116, Bulletin 349, U. S. Geological Survey. The analysis was made by C. H. Stone at the structural materials testing laboratory, U. S. Geological Survey, St. Louis, Missouri.

Silica	60.54
Alumina	25.89
Ferric oxide	1.75
Manganese oxide	.26
Lime	.53
Magnesia	.12
Potash	1.85
Soda	.65
Water	2.05
Loss on ignition	7.43
Sulphuric anhydride	.12
	101.19

HITCHINS.—The Olive Hill Fire Brick Company is now constructing at Hitchins what is said to be the largest fire brick plant in the world. The plant is located at the junction of the Cheaspeake & Ohio and the Eastern Kentucky Railroads. No amount of money has apparently been spared in making it one of the most up-to-date plants of its kind.

The floor space of the main dry room is 156 by 192 feet. In addition to this there is a large power house, which contains a 350-horse power engine and 400-horse power boiler; a pan room, and an apparatus house. The pan room contains two large dry pans, two pug mills and two large brick machines. Most of the bricks will be machine-made. The apparatus house contains one 14-foot steel induction fan, and an exhaust fan 12 feet in diameter. These will used to control the waste heat from the kilns in drying the bricks.

The entire structure is made of steel and concrete frame, with walls of cement plastering on steel Hy-rib, and covered with asbestos-protected metal roofing.

Each piece of machinery will be run by a separate dynamo.

The company now has ten 30-foot round, down-draft kilns of 80,000 bricks each capacity, and it is the intention to erect in the near future ten more of the same size. The kilns are built twin-fashion and the waste heat, after a kiln of brick is burned, will be conducted through a main cement-lined tunnel to the dry shed, where it will be used to dry the green bricks. The waste heat from any kiln can also be conducted to any other kiln and there used for drying the green bricks. Each kiln is made separate or thrown into the main hot air current by means of a steel damper.

The purpose of the induction fan is to draw the waste heat from the kilns and force it to the dry room. A part of this heat will be conducted through flues leading off from the main tunnel beneath a stone floor which is constructed of Rowan county sawed stone. The green bricks will be laid on this smooth floor to dry. Opposite the dry floor are twelve small tunnels constructed at a right angle to and connected with the main tunnel. These tunnels are 100 feet in length and are built air tight. They are

constructed with tracks of one per cent grade so that small cars of green bricks can be pushed in and dried on the cars. The cars will be pushed in the tunnels from the end next to the pan room where the bricks are to be made. When dry enough to set in the kilns they will be forced on through the tunnels to the kilns and the tunnels refilled as before.

The heat from the main tunnel can be directed to the dry floor or to any set of tunnels by means of deflector dampers.

The 12-foot exhaust fan will draw the heat from the dry floor and the small tunnels through a return tunnel and force it out through a large stack built at the apparatus house for that purpose.

In case there should not be sufficient waste heat from the kilns to dry the bricks, it is arranged to dry a part of them by means of exhaust steam.

The daily capacity of the plant when completed will be 100,000 bricks.

The plant was designed by the L. E. Rodgers Engineering Company, of Chicago, and constructed under the supervision of Clayton S. Hitchins, of Olive Hill.

The company owns about 450 acres of land lying to the east of the plant. The clay to be used at the plant is expected to be derived from the bed associated with the Ferriferous limestone. At Willard, at Denton, four miles east of Hitchins, at Ashland, and at Music, the fire clay of the Ferriferous limestone horizon is near the base of the hills and is found in continuous beds of good quality. Hitchins is located at the western border of the area underlain by the limestone and associated clay. The first hills to the east of the plant are not high enough to catch the limestone and the clay. About one mile east of the plant the highest crest rises 300 feet above the plant. Seventy feet below the crest the fire clay has been uncovered at about the horizon of the Ferriferous limestone. The place is marked by the presence of old iron ore diggings. The clay occurring as it does within 70 feet of the crest of the highest ridges, there is a very small proportion of the land owned by the company underlain by the clay. The main body of the clay lies to

the east where the eastward dip carries it down near the base of the hills and gives a larger workable area.

It will require a large area of workable clay to supply the demand of a plant that is to produce 50,000 to 100,000 bricks a day for an indefinite length of time. There are three possible sources where clay may be obtained. The plastic variety may be obtained in the hills farther east in the vicinity of Denton and Music, and on the head waters of Robin Run and Upper Stinson creeks; or it could be obtained to the south in the vicinity of Willard. If flint clay is to be used the nearest deposits would be in the Big Sinking creek territory or in the hills south of the Chesapeake & Ohio Railroad between Cory and Grahn. The hills between Dry Fork and Grassy Fork of Gorman Fork may be worthy of further investigation.

There is also a possibility of getting the Olive Hill flint clay below the surface at Hitchins. It was found to be ten feet thick in one of the oil wells at Denton. It occurred just above the Mississippian limestone with fifteen feet of blue shale above the clay and between it and the Conglomerate sandstone. The fire clay was struck at a depth of 625 feet below the surface. The rise of the strata to the west would bring the Olive Hill flint clay horizon to within about 350 feet of the surface at Hitchins. Could it be found of good quality and seven to ten feet in thickness, it would be more economical to mine it even at that depth than it would be to haul it from the Olive Hill district. Its presence or absence could be determined by means of a core drill.

Considerable excavation has been done in the hills east of the plant in an effort to locate the fire clay deposits. The following is a section of the hill from near the "Blue Jay" coal mine to the clay opening at the head of the branch. The entire thickness of the section is about 300 feet.

		Feet	Inches.
28	Crest of high hill.		
27	Covered. Ferriferous limestone comes near base	70	
26	Plastic clay containing thin irregular pockets of flint clay	25	

		Feet	Inches
25	Gray laminated shale which weathers to a bluish clay	2	
24	Gray plastic clay with two inches of dark clay in the center	1	
23	Black shale	....	21
22	Coal	....	13
21	Irregular bodies of stratified clay	4	
20	Pale drab stratified fire clay	....	20
19	Dove colored fire clay with streaks of iron oxide	....	12
18	Dove colored fire clay, uniform in color	....	18
17	Gray micaceous sandstone about	15	
16	Covered	....	
15	Sandstone	....	
14	Shale	3-4	
13	Coal	....	1
12	Draw slate	1	
11	Coal	....	21
10	Bone	....	3
9	Coal	....	14
8	Fire clay	....	
7	Shale	25	
6	Sandstone changing to shale at same horizon	50	
5	Gray shale	25	
4	Coal	....	3
3	Sandstone, hard on bottom and shaley on top	6	
2	Black shale	20	
1	Sandstone.		

The fire clay occurring from 18 to 21 inclusive is the most promising horizon of the section. At horizon 26 is a deposit of laminated, micaceous shale which contains irregular blocks of flint clay. In places it occurs in kidney-shaped forms. The color is not uniform, but shows finely stratified lines of white, light gray to dark gray sand in the clay.

The quality of the clays from the Hitchins property is shown in the following analyses and tests made by J. M. Knote, of the Pittsburg Testing Laboratory. The following results and remarks of J. M. Knote were kindly furnished the writer by Mr. Hitchins, General Manager of the Olive Hill Fire Brick Company, Olive Hill:

	Loss on Ignition.	Silica.	Oxide Iron.	Oxide Aluminum.	Oxide Calcium	Oxide Magn.	Titanic Acid.	Alkalies.	Fusion Cone.	
1.	12.24	53.30	.71	30.88	.50	.03	2.21	.12	34	3290°F.
2.	8.16	58.90	1.71	26.23	.45	.03	1.28	3.49	24½	3092°F.
3.	10.32	53.46	1.71	27.89	.60	.20	1.48	1.45	23	3182°F.
4.	8.48	64.28	.71	23.51	.50	.08	1.51	.99	31	3182°F.

(1) "Flint clay from bottom seam. Shrank from 12 to 11 1-10 inches on burning. No shrinkage after cone 9. An excellent clay and while a little higher in silica than those at Olive Hill, it should make very good brick. It is as good as the best Missouri, Pennsylvania and Maryland flint clays.

(2) "Plastic clay. Shrank from 12 to 11 inches on drying and to 10½ inches on burning. A very plastic and strong bond clay. It dries with a normal shrinkage and burns to a dense strong body at cone 3 and remains thus without change to cone 11. It would doubtless show little change up to cone 22-25. Its burning shrinkage is normal. The clay is as plastic and strong as any but the exceptional fire clays. It vitrifies three or four cones lower than the Maryland clays, but about the same as most Pennsylvania clays. The Missouri clays are much more porous at cone 11. In refractoriness it is just about the same as the best Savage Mountain clay or Pennsylvania clays. I consider it a very good bond clay.

(3) "Plastic clay. Shrank from 12 to 11 2-8 inches on drying and to 10½ inches on burning. Nearly out at cone 3; all out at cone 7-9. Similar to No. 2 in every way.

(4) "Flint clay. Shrank from 12 to 11 2-10 inches. All out at cone 9. This clay is a second grade flint clay and while of probable value for second grade brick, it is not as valuable as clay No. 1."

DENTON.—In 1908 the Denton Plastic Clay Company, of Denton, opened a clay mine about 200 yards east of Denton, on the main line of the Chesapeake & Ohio Railroad. The mine is located about 200 feet above the railroad track. It is worked by horizontal drift and the clay

loaded into clay cars, which are pushed by hand to a tipple built on a side track of the railroad, and dumped directly into open freight cars.

The raw clay from the Denton mine is shipped to Charles Taylor's Sons, Cincinnati; to the Louisville Pottery Company, Louisville; to the Rookwood Pottery Company, Cincinnati; and to the Harbison-Walker Refractories Company, Olive Hill. The monthly shipments average nine cars of 45 tons to the car.

The clay occurs at the horizon of the Ferriferous limestone although no limestone is present here. It is the same clay that occurs 70 feet below the top of the highest hills one mile east of Hitchins. The following is a section of the mine.

Elevation of mouth of mine 680 feet above sea level.

	Feet	Inches
Light gray shale.		
Laminated micaceous sandstone	6	
Dark clay	4	
Coal		10
Black plastic clay—not worked	5	
Dark, hard, siliceous clay—not used		4
Plastic clay containing boulders of silica	8	
Gannister	4	

BURDETTE CLAY MINE.—Mr. J. H. Burdett, of Ashland, in 1907 opened a clay mine one mile east of Denton. The mine is located on the north side of the Chesapeake & Ohio Railroad. It is operated and the clay is loaded into the cars as it is done at the Denton mine. The principal part of the clay is shipped to the National Fire Brick Company, of Strasburg, Ohio.

The geologic horizon of the Burdette mine is the same as the Denton mine, although it is about 70 feet higher elevation. There is a strong westward dip of the strata between the Burdette mine and Denton, as shown by coal number 4 which outcrops at the level of the railroad track at the Burdette switch. For a distance of one-fourth of a mile west of the switch the coal is practically horizontal. Farther west the coal dips rapidly to the west and disappears beneath the level of the railroad track a short distance east of Denton, notwith-

standing a grade to the west in the railroad between the two points of 65 feet to the mile.

The opening of the clay mine is just above a massive, coarse-grained sandstone which is about 55 feet thick at this place. The Ferriferous limestone which comes at about the horizon of the fire clay deposit is absent in this locality. The following is a section at the mine:

	Feet	Inches
Coal of good quality	....	14
Black plastic clay	4-6	
Dark, hard siliceous clay which breaks up into cubical blocks when exposed to the weathering agents and locally known as "Nigger heads"	....	2-4
Good No. 2 plastic clay	6	
Gannister	4	

Hard siliceous gannister boulders are frequently found in the No. 2 plastic clay. In places these boulders cut out part of the clay.

The elevation of the clay mine is about 755 feet above sea level.

About 55 feet above the clay mine is a bed of flint clay. It is marked on the hill side by a distinct bench. Fragments of the flint clay were found at this horizon but the thickness of the deposit was not determined.

MUSIC.—Music is located on the east side of Means Tunnel, two miles east of the Burdette mine. The strata from the Burdett mine to Denton have a strong westward dip, whereas those east of Means Tunnel dip to the east. There is, therefore, a well-defined anticline the crest of which is located near the tunnel.

A deposit of No. 2 plastic fire clay was opened at Music in 1911 on the Lexington and Carter County Mining Company's land in the hill just north of the Chesapeake & Ohio Railroad. Mr. T. M. McGlohon, manager of the property, sent a sample of the clay to the Rookwood Pottery Company, of Cincinnati, and had it tested for making pottery. They pronounced it a very satisfactory clay for that purpose.

The opening from which the clay was obtained was driven 25 feet into the hill. The No. 2 plastic clay is nine feet thick. Weathered streaks of iron oxide extend

through the clay, but do not affect its quality. The clay rests on a siliceous gannister rock similar to that at the Denton and the Burdette mines. A thin coal occurs near the top of the clay.

The elevation of the mine is about 720 feet above sea level.

Two miles east of north of Music a deposit of No. 1 flint clay is reported to have been opened. The deposit is said to be three and a half feet thick.

The clay which occurs at Denton, Burdette mine, and Music is a very persistent formation and may be found underlying a large territory in the hills adjacent to the Chesapeake and Ohio Railroad from Denton to Ashland.

ASHLAND.—The Ashland Fire Brick Company operates two fire brick plants in west Ashland. The larger is known as the Ashland Fire Brick plant and the smaller as the Clinton Fire Brick plant. While they are owned by the same company they are operated as separate plants.

The Ashland Fire Brick Company is located on a spur of the Ashland Coal and Iron Railroad. The clay is dumped from the car as it comes from the mine into a large hopper which contains a grinder, where it is crushed and then conveyed by an overhead electric car to the open yard. Each grade of clay is kept separate. The clay is allowed to remain on the yard exposed to the weathering agents for several months. The weathering mellows the clay, leaches out some of the impurities, and improves its general working qualities.

After the clay is thoroughly mellowed, it is reground in a Clearfield dry pan. The desired mixture of flint clay, calcine and plastic clay are then made and the contents mixed with water and thoroughly kneaded into a stiff mud ready for the molders. The kneading is done in two Clearfield wet pans.

All the bricks made at this plant are hand-molded. The plain bricks are molded and allowed to dry for a certain length of time when they are repressed in hand-power represses. More care is used in molding the shaped bricks and large blocks as they are not repressed. When nearly dry the faces and serrated edges are wet with water and smoothed with a small trowel.

The bricks are dried on a cement floor heated from beneath by exhaust steam from the boiler. No waste heat from the kilns is used in drying the bricks.

The plant is supplied with a 225 horse-power boiler and an engine of the same size. All of the machinery of the plant is run by electricity with a dynamo for each machine.

The output of the plant ranges from 19,000 to 20,000 bricks a day. Four thousand one hundred bricks to the man are considered a day's task, which is accomplished in five to six hours.

The bricks are burned in round, down-draft kilns. There are six kilns with a capacity of 80,000 bricks each. Natural gas is used in burning the bricks. It takes about four days to drive off all of the water and to get the kiln to a good red heat. About two and a half days more are required to bring the kiln to a bright white heat, where it is held for a day and a half. It requires about one day longer to burn the bricks with gas than it does with coal, but the gas gives a more uniform heat throughout the kiln as there is no choking of the draft. On the whole the gas is more economical than coal, in the first cost of the fuel, requires less labor to operate it, is cleaner, and gives a more uniform burn.

The finished product of this plant goes to all parts of the United States, to Canada, Cuba, Old Mexico and Japan.

The clay used at the Ashland Fire Brick plant is derived from two sources. The calcine and the flint clay come from the company's mine at Hayward, in the Olive Hill district. The No. 2 plastic clay comes from the Ashland district. The mine is located in the high bluff facing the Ohio river one mile west of Ashland. The mouth of the mine is about 25 feet above the track of the Chesapeake and Ohio Railroad. The clay is dumped from the mine cars into the railroad cars over a tipple. The clay comes from the same geological horizon as the clay from the Willard and the Denton clay mines. The following is a section of the Ashland mine:

	Feet.
Sandstone	12
Coal	3
Plastic fire clay—not used	2-3
Sandstone	10-12
White to drab potter's clay	5
Shale containing iron ore	4
No. 2 plastic fire clay of a dark color	3½-4
Ferriferous limestone in places partly replaced by carbonate of iron	1-7
No. 2 White, plastic fire clay	3-8
Gannister.	

The following analyses of the clays from this place were made by Robert Peter and furnished W. C. Phalen in Bulletin 349, U. S. Geological Survey, page 116, by the Ashland Fire Brick Company:

	(1)	(2)
Silica	40.14	56.40
Alumina	43.72	28.00
Ferric oxide	1.98	
Lime, Magnesia	1.60	1.30
Water	12.56	14.30

No. 1 is from the upper stratum and No. 2 from the lower stratum given in the above section.

About 40 feet above the top of the above noted section is a thin coal which has been worked for local use. One hundred feet above the Ferriferous limestone in the same hill is a deposit of flint clay which was worked years ago but was abandoned on account of the large percentage of iron it contained.

The Clinton Fire Brick plant is owned and operated by the Ashland Fire Brick Company. It is located a short distance west of the Ashland Coal and Iron Company's Blast Furnace. The clay used at this plant comes from the same sources as that used at the main plant.

The plant uses about twenty-eight tons of flint clay and four tons of calcine a day from the Hayward mine. This is mixed with the No. 2 plastic clay from the Ashland mine as a bond. The output of the plant is 8,000 bricks a day. Only high grade, handmolded bricks are made. They are dried on a hot floor heated from beneath by dry heat generated by the combustion of coal.

The green bricks are laid on the hot floor and dried for about two and a half hours and are then repressed. After repressing they are placed on the floor at the end farthest removed from where the hot air enters the dryer and dried for about three days longer.

The plant is equipped with five round, down-draft kilns with only one stack to the kiln. Three of the kilns have a capacity of 50,000 bricks each; one has a capacity of 60,000 and one of 80,000. Gas is used as fuel for burning the bricks. Eight to nine days are required to burn a kiln of bricks.

The Ferriferous limestone and the accompanying deposit of fire clay continues down the Ohio River from Ashland to near the mouth of Yewlands creek, four miles above Greenup. At the site of the old Amanda Furnace two miles below Ashland, the fire clay has been worked and shipped to Cincinnati and to the Taylor fire brick plant at McCall. The following section of the mine was given by one of the men who worked in the mine:

	Feet	Inches.
Shale to top of the hill.		
Sandstone	....	4
Good coal	....	15-16
Parting	....	1
Coal	....	15
Shale parting	....	4
Coal—good quality	....	8-14
Sandstone	20	
Potters clay	4-9	
Green shale	2	6
Red limestone ore	½-1	
Ferriferous limestone	6-9	
No. 2 plastic fire clay	5-7	
Gannister used at steel plant for lining cupelos	....	18-20
Heavy-bedded sandstone	25-40	

The fire clay associated with the Ferriferous limestone has been opened on the O'Kelly Brick Company's property in east Ashland. The fire clay here is seven feet thick with a thin parting of black bony slate near the center. Mr. O'Kelly expects to use this clay in connection with a fire clay that occurs fifty feet lower just beneath coal number four, which outcrops in the same hill, in the manufacture of fire brick.

WEAVER POTTERY COMPANY.—At the Weaver Pottery Company's plant near Cliffside Park, between Ashland and Catlettsburg, the fire clay at the Ferriferous limestone horizon is being used in the manufacture of jugs, churns and similar wares.

The clay used at this plant rests directly on the Ferriferous limestone. There is an interval of eight feet between the lowest bed of clay that is now being worked to the top of the heavy-bedded sandstone which forms the cliff between Ashland and Catlettsburg. The thickness of the clay varies from four to five feet. The color of the clay varies from dark near the top to a light drab below. A band of bony slate one to two inches in thickness with a thin coal occurs near the top of the clay. Above this is a dark plastic clay the thickness of which was not determined.

Forty feet below the clay opening, at the base of the cliff-forming sandstone, coal number four is now being mined and used at the pottery plant. The coal is three feet thick at this place. Underneath the coal is a deposit of fire clay three feet in thickness. This is the same coal that has been opened on the O'Kelly property in east Ashland.

The plant has one round, down-draft kiln of 4,500 gallons capacity. It requires sixty hours to burn the ware. Coal is used as the fuel.

ECONOMIC PRODUCTS OTHER THAN FIRE CLAYS INCLUDED IN THE AREA OF THIS REPORT.

A number of industries utilizing raw materials found in the area included in this report deserve mention here. In a few instances the raw materials are shipped outside of the district where they are converted into finished products. The economic commodities consist of coals, limestones, shales, asphalt, iron ores, glass sand, sandstone, oil and gas.

COAL.—Workable beds of coal are found in the area east of Little Sandy River, and, to a slight extent west of it. The coals include those from the base of the Coal Measures up to and including coal No. 7. The greater amount of the coals belongs to the bituminous variety. The most promising beds are those found along the

Chesapeake and Ohio Railroad from Denton to Ashland. An excellent variety of cannel coal is mined near Hunnewell, Boghead and Willard.

LIMESTONES.—Brief descriptions have been given of the Mississippian limestone, which is found associated with the fire clays of the Olive Hill district, and the Ferriferous limestone which is found in the Ashland district.

The Ferriferous limestone is mined in the vicinity of Ashland and used as a flux in the blast furnaces at that place. At Ironton, Ohio, it is used with the accompanying fire clay in the manufacture of Portland cement. It is a fairly pure limestone, but at no place in the area is it of sufficient thickness to be profitably mined except as a byproduct of the accompanying fire clay deposit.

A discussion of the area, thickness and extent of the Mississippian limestone has been given under the discussion of the geology of the region.

Quite an industry has developed along the three divisions of the Chesapeake and Ohio Railway of this area in crushing the Mississippian limestone for railroad ballast. The crushed stone is sold f. o. b. cars at the crushers at fifty-five cents a cubic yard. The stone is crushed to pass through a 2¾ inch ring. There are two crushers at Olive Hill, one at Enterprise, one at Lawton, two at Carter and one at Tongs, P. O. A brief description of these plants follows:

CHESAPEAKE STONE COMPANY.—This plant is located at Highland at the mouth of Cory creek, one and one-half miles east of Olive Hill. The crusher is built within a few feet of the Chesapeake and Ohio Railroad. The stone is obtained from the quarry which is located on either side of the railroad. That on the north side is quarried and conveyed to the crusher on the south side through a tunnel under the railroad track. The quarry is equipped with five large and five small Ingersoll Rand steam drills. The rock is blasted out of the quarry by dynamite and conveyed over a narrow gauge railroad to the crusher by means of a small steam engine. The stone is crushed by two Gates' mills, a 7-B and 4-K, which have a combined capacity of 600 cubic yards a day exclusive of the dust.

The vertical face of the quarry measures seventy-two feet. The upper bench, which is eight feet thick, is separated from the main ledge by five feet of green shale

which contains a thin band of limestone three inches thick. The limestone above the bed of green shale is a comparatively pure white limestone which weathers into a very irregular surface. It has the general appearance of the St. Genevieve limestone of Western Kentucky. The upper part of the main ledge is of a bluish color, very hard, and contains numerous round and oblong flint nodules similar to the St. Louis.

The following is an analysis of a sample of the grayish white stone from this quarry made by J. S. McHargue. Sample collected by J. P. Nelson.

Analysis of Air Dried Sample.

	Per cent.
Moisture	.04
Ignition (carbon dioxide, organic matter, etc.)	34.30
Silica	20.06
Alumina and trace of phosphorous pentoxide	4.48
Ferric oxide (equivalent to 4.18% ferrous carbonate)	2.88
Lime (equivalent to 50.00% calcium carbonate)	28.00
Magnesia (equivalent to 21.36% magnesia carbonate)	10.17
Total	99.93

ATLAS STONE COMPANY. This plant is located on the north side of the Chesapeake and Ohio Railroad bridge across Tygart creek one mile east of Olive Hill. The stone is the same as that used at the Chesapeake Stone Company's plant. The thickness of the bed now being worked is about eighty feet. The hill above the quarry has a steep slope and contains only two to four feet of overburden.

The quarry is equipped with three large Ingersoll Sargent and two small, hammer, steam drills. In addition to these they have a six-inch Cyclone steam churn drill, the kind ordinarily used in well-drilling.

The stone is conveyed to the crusher in small cars drawn by mules. The plant is equipped with one No. 8 and two No. 5 Gates' rock crushers. Seven to ten car loads of stone are crushed daily. The crushed stone is sold to the Chesapeake and Ohio Railroad Company for railroad ballast. The following analysis of a sample of stone from this quarry was made in the chemical laboratory of the Survey by J. S. McHargue, Survey Chemist. Sample collected by J. P. Nelson.

Analysis of Air Dried Sample.	Per cent.
Moisture	.05
Ignition (carbon dioxide, organic matter, etc.)	42.15
Silica	1.64
Alumina and trace of phosphorous pentoxide	.38
Ferric oxide	.48
Lime (equivalent to 97.10% calcium carbonate)	54.88
Magnesia (equivalent to 0.67% magnesium carbonate)	.32
Total	99.90

LIMESTONE MINING COMPANY.—The Limestone Mining Company established a stone crusher at Limestone in 1904. They are using the Mississippian limestone for railroad ballast. The limestone is here near the top of the hill. It is broken down with dynamite and loaded into small cars which are run over a seventy-five foot embankment into the crusher.

The stone is crushed in a No. 5 Austin mill, and an Aurora mill No. 2. The daily capacity of the plant is 300 cubic yards of crushed stone.

The following is a section of the quarry:

	Feet.
Overburden	10
Hard blue limestone	13
Pure white, oolitic limestone	10
Thin, stratified stone containing flint nodules	13
Purple, stiff clay	3
White, pure limestone	6
Hard blue ledge with small oval shaped flint nodules	27
Base of Quarry.	

The following is an analysis of the hard, white stone from this quarry. The sample was collected by J. P. Nelson. Analysis made by J. S. McHargue.

Analysis of Sample, Dried at 100° C.	Per cent.
Moisture	.05
Ignition (carbon dioxide, organic matter, etc.)	40.71
Silica	4.94
Alumina and trace of phosphorous pentoxide	1.22
Ferric oxide	.48
Lime (equivalent to 92.50% calcium carbonate)	51.80
Magnesia (equivalent to 1.60% magnesium carbonate)	.76
Total	99.96

LAWTON LIMESTONE COMPANY.—The Lawton Limestone Company of Lawton station, which is located on the Chesapeake and Ohio Railroad three miles west of Limestone, is operating a stone quarry in the Mississippian limestone. A ledge thirty feet in thickness is quarried and the purest part is shipped to the Ashland Iron Works for flux. The refuse is crushed for railroad ballast. The output of the plant is 300 tons a day.

CARTER CRUSHER COMPANY.—About 1 mile up Smith creek from the town of Carter the Carter Crusher Company is working a ninety-foot ledge of Mississippian limestone. The stone is crushed and used as ballast by the Chesapeake and Ohio Railroad Company. The company operates two Gates' crushers, one No. 7½ and one No. 5.

POPULAR BALLAST COMPANY. Two miles above Carter on the south side of Smith creek the Popular Ballast Company of Carter is working a ninety foot ledge of Mississippian limestone. The stone is crushed and used exclusively for railroad ballast. The full thickness of the limestone at this place is 130 feet but the upper 30 feet are partly hidden and perhaps interbedded with shale.

The plant has a capacity of twenty cars of crushed stone a day. The largest daily output has been seventeen cars, with a daily average of fifteen cars.

The base of the limestone is about 125 feet above the track of the Chesapeake and Ohio Railroad. A large No. 7½ Gates' crusher is located at the base of the limestone outcrop. The broken rock from the quarry is conveyed to the crusher in side-swing steel dump cars drawn by a steam engine and dumped directly into the crusher which is constructed at the bottom of a funnel-shaped bin. From the large crusher the broken stone passess by gravitation to a No. 5 rebraker and from here it is conveyed over an endless belt, twenty-four inches wide, to the chute and loaded into the cars. From the time the stone is dumped into the large crusher until it falls into the cars 125 feet below it is assisted by the action of gravitation.

The quarry is equipped with three Ingersoll Rand air compresser drills. It is the intention of the company

to install a six-inch Cyclone well drill which will be used to drill a line of holes parallel to face of the quarry.

The quarry drills are operated by an Ingersoll Rand Automatic air compressor.

WILSON BALLAST COMPANY. In 1910 the Wilson Ballast Company established a crusher plant at Tongs, P. O., eight miles north of Greenup. A section of the quarry was given on another page of this report. The plant was shut down in August, 1912. The limestone that was used for ballast is only thirty feet in thickness, and is overlain by sixty-five feet of sandstone and shale which prevented the limestone being worked at a profit.

The following analysis of a sample of stone from this place was made by J. S. McHargue, the Survey Chemist. Sample collected by A. F. Foerste.

Analysis of Sample, Dried at 100° C.

	Per cent.
Moisture	.18
Ignition (carbon dioxide, organic matter, etc.)	41.30
Silica	7.10
Alumina	1.60
Ferric oxide	2.40
Lime (equivalent to 56.42% calcium carbonate)	31.60
Magnesia (equivalent to 32.52% magnesium carbonate)	16.26
Phosphorous pentoxide	Tr.
Sulphur	Tr.
Alkalies	Tr.
Total	100.44

SHALES.—Very little attention has been paid to the valuable shale deposits of this part of Kentucky. Located as they are in a region of abundant cheap fuel and bordering a large territory to the west where it is impossible to obtain raw material of this kind, there is no reason why the deposits which are located on the railroad lines traversing this region should not be utilized.

The Waverly shales which outcrop in the town and for a distance of one or two miles west of Morehead could be made into sewer pipe, paving brick, English face brick, and perhaps terra cotta, roofing, coping, etc. This same

bed is now being utilized at Indian Run and at Portsmouth, Ohio, in the manufacture of paving brick.

Thick deposits of Coal Measure shales outcrop on the Chesapeake and Ohio Railroad two miles east of Olive Hill, and again in the town of Hitchins.

Paving brick shales are also found in the high bluff facing the Ohio River at Greenup. A plant could be located here near the terminus of the Eastern Kentucky Railroad and on the main line of the Chesapeake & Ohio Railroad. Coal Measure shales are found at intervals between Greenup and Ashland on the Chesapeake & Ohio Railroad, and also along the Eastern Kentucky Railroad from Greenup to Willard.

PORTSMOUTH GRANITE BRICK COMPANY.—Some idea may be obtained as to the value of the shales of this region by a glance into the plant of the Portsmouth Granite Brick Company, located two miles west of South Portsmouth, near the mouth of Indian Run.

The plant was originally equipped as a fire brick plant. The fire clay was obtained on Dry Fork of Schultz Creek, seven miles to the southeast in Greenup County. On account of the poor quality of fire clay used and the expense of getting it to the plant, it was finally sold to the present company and converted into a paving brick plant.

The shales used here are found in abundance right at the plant. They occur in three zones. The lowest zone near the base of the hill is a dark blue unweathered shale which is not used on account of containing too much iron and alkalies.

Above the dark unweathered shales is a semi-weathered zone where much of the impurities have been removed by the leaching action of carbonated waters in the presence of air. In this the sulphide of iron has been converted into the oxide which stains the shales red and brown.

Above this is a zone of still greater weathering where the material has been broken up into a soil. A mixture consisting of fifty-five per cent from the upper zone and forty-five per cent from the middle zone is used in making the pavers.

The plant is equipped with two dry pans for grinding the mixture as it comes from the bank. It is then tempered and pugged in a Fate, stiff mud, side, wire-cut

brick machine. The bricks are repressed in a power press and the name "Granite Block" imprinted on each brick.

The bricks are dried in drying tunnels which are equipped with two large fans. One fan draws the waste heat from the kilns into the dryer and another is used to draw off the moisture from the drying bricks. The bricks remain in the dryer thirty-six hours. The dryer has a capacity of 44,000 bricks. The dry floor originally used for drying fire brick is used as an accessory dryer for the pavers.

There are six round, down-draft kilns, four of which hold 30,000 bricks each, and two hold 43,000 each. There are two square kilns which have a capacity of 30,000 each. It requires eight to nine days to burn a kiln of bricks. Coal is used as fuel.

ASPHALT.—About one mile due south of Soldier, on the property of Whitt and King, is an outcrop of asphalt at an elevation of 1,040 feet above sea level. It is a coarse-grained sandstone which is completely saturated with oil. Where exposed to the sun for a day or two the black oil runs out of the rock. An 18-inch seam of coal outcrops just above the asphalt rock on the opposite side of the hill. The following is a section made at the asphalt opening:

	Feet.	Inches.
Gray sandstone.		
Stratified gray clay	....	12
Gray sandstone	....	2
Gray, stratified, plastic clay	....	6
Asphalt rock	4-6	
Gray plastic clay.		

A short distance down the same branch and a few feet below the asphalt horizon, is an outcrop of the Mississippian limestone which lies just below the fire clay.

There is an interesting relation of the asphalt rock to the fire clay of this region. The asphalt rock occupies a geological horizon just above the fire clay. In some places where the fire clay is absent the asphalt may be found below the horizon of the fire clay, or it may be so thoroughly disseminated through the rocks that it has not accumulated to any extent.

The asphalt rock was opened on J. P. Danner's place one-half mile west of Soldier; on J. D. Patton's land across the branch from Danner's; and again on L. S. Vincent's land one quarter of a mile northeast of Soldier.

At Mr. Danner's there is a ledge of sandstone 14 feet thick, the lower 6 feet of which is rich in asphalt. The asphalt rock here rests directly on the fire clay.

About the same conditions exist at Mr. Patton's as are found at the Danner place.

The asphalt at Mr. Vincent's outcrop is found in a stratified sandstone fully 20 feet below the fire clay. Boulders of limestone and fragments of fire clay are present on the opposite side of the hill from where the asphalt is found.

The asphalt is nothing more or less than a sandstone which has become saturated with oil. Were it not for the underlying impervious fire clay the oil in many places would not have collected where it has. In some places the oil found its way into pockets of the clay. At the J. D. Patton clay mine a hole for a shot was made in the top of the clay and the augur struck into a pocket of oil and two or three gallons of thick oil ran down into the mine.

IRON ORES.—Iron ores were extensively mined in this region in the early seventies. A large number of abandoned charcoal furnaces in various parts of the era attest the high esteem in which the iron from this district was held. The ore occurred in irregular packets and was mined in a very crude manner. The furnaces were operated as long as the ore could be obtained in such workings, but on exhaustion of these pockets the expense of mining the ore in a systematic manner was too great and the furnaces were shut down.

GLASS SAND.—A fine grained sandstone which occurs near the base of the Coal Measure rocks is now being mined at Lawton by the Hillman Sand Company, and shipped to Charleston Window Glass Company, the Banner Window Glass Company and the Dunkirk Window Class Company, all of Charleston, West Virginia.

The sandstone ledge used for this purpose is thirty-five feet thick and crushes to fine sharp grains of almost

pure quartz. The output of the plant is about 1,000 tons a month.

SANDSTONE.—In a few localities the fine-grained sandstone which occurs above the heavy-bedded Conglomerate has been used locally for foundation stones, milk houses, and other buildings. It is easily worked when fresh from the quarry and makes a beautiful gray, and very desirable structure. It has no superior as a foundation for bridges and piers, and would make a desirable building stone for dwellings.

A profitable industry could be established at a number of points along the Chesapeake & Ohio Railroad between Soldier and Hitchins in crushing the coarse-grained, loosely cemented Conglomerate sandstone for a building sand. At Cory, Grahn, and Aden the sandstone forms high cliffs along the railroad. Such an industry should be a profitable one in view of the fact that all of the sand used in the central limestone region of Kentucky has to be shipped in.

OIL AND GAS.—Oil and gas wells have been drilled in different parts of this area with varying degrees of success. An oil well was drilled in 1911 on Mr. L. S. Vincent's land one-fourth of a mile north of Soldier. The well was drilled to a depth of 978 feet where a heavy flow of salt water stopped the drilling. The fresh water was cased off at a depth of 230 feet and it was a dry hole to a depth of 950 feet where a light flow of oil was struck. The following is a section of the well made by Mr. Vincent.

	Thickness	Depth.
Gray limestone	530	530
Black shale	410	940
Gray clay containing gas and oil	10	950
Sand, oil and gas-bearing and salt water in bottom	28	978

The salt water rose in the well to within 170 feet of the surface, and oil now stands 75 feet deep on top of the salt water. Gas still flows from the well and burns when ignited with a match.

The well was started fifty feet below the top of the Waverly sandstone, on the eastern flank of an anticline, the north-south crest of which is about one-half mile

to the west. It is possible that a well a short distance to the west nearer the crest of the anticline would strike a larger flow of oil at the same depth.

Wild cat wells have been drilled at Lawton, Cory, Grayson and Denton. The following is a log of Queen Farm Well No. 1, Denton. The well was started 50 feet below Coal No. 7.

	Thickness.	Depth.
Surface	10	10
Blue shale	100	110
Water sand	60	170
Blue shale	320	490
White sand	120	610
Blue shale	15	625
Fire clay	10	635
White lime	125	760
Red clay	10	770
Blue shale	65	835
Big Injun sand	165	1,000
"Hard shell"	40	1,040
Blue shale	205	1,245
"Berea Grit"	90	1,335

The well was completed after the writer's visit to it, but no oil was reported.

An oil well was drilled at Carter on Buffalo Creek in 1902 by some parties from Carter. The following is a log of the well:

	Thickness.	Depth.
Soil	14	14
Freestone	86	100
Blue shale	84	184
Sand—trace of oil and gas	28	212
Gray shale	278	490
Black shale	60	550
Fire clay—white	10	560
Close sand containing gas	40	600
Gray shale	50	650
Black shale	325	975
Fire clay—white	60	1,035

Sand and salt water rose to the surface. When first completed the gas from the well had a pressure of

27 pounds. It now has a 30-pound pressure and is used in Carter for heating and lighting purposes.

The well was started 175 feet below the top of the Waverly.

A number of factories in the town of Ashland are now using natural gas secured from wells in the vicinity of Ashland.

At the Means and Russell Iron Company's brick plant, 1¼ miles west of Ashland at the mouth of Hood's creek, a gas well of 1,710 feet deep was brought in June, 1912. Gas from this well is obtained for drying and burning 1,000,000 bricks a year, and also supplies fuel for the boilers.

The well was started at an elevation of 520 feet above sea level, and 80 feet below the Ferriferous limestone.

CHAPTER VI.

ORIGIN AND NATURE OF CLAY.

There are two distinct viewpoints to be considered in defining clay. From the standpoint of the practical clay worker clay is an earthy substance which when mixed with the proper proportion of water and thoroughly kneaded becomes a plastic mass that remains constant when molded into any desired shape. Thus it is seen that plasticity is primarily the essential economic characteristic of clay. It is one of the principle properties that has made clay one of the most useful natural substances of modern times. There are some highly refractory flint clays and pure kaolins that do not possess the property of plasticity and from this standpoint, therefore, would be excluded from the category of clays. However these non-plastic materials become valuable as clay products when used with some bonding material.

The chemical definition of clay more clearly defines it with reference to its composition without any bearing on its physical properties. Kaolinite, the purest form of clay is a hydrous silicate of alumina. Some white clays, and the flint clays such as are found in Carter County, Kentucky, approach the composition of kaolinite. Most of these, however, are non-plastic and in their natural state, except being refractory, have lit-

tle in common with the plastic clays. Most of the highly flint refractory clays and the kaolins would come within the chemical definition but would be excluded under the term of "an earthy substance that becomes plastic when mixed with a certain amount of water." In like manner most clays that have the quality of plasticity cannot be classed as kaolin. There is a wide range in composition from the purest kaolin to the argillaceous sands.

A definition of clay, therefore, should include the wide range of plasticity, and likewise the extremes in chemical composition. Clay may thus be said to be an earthy substance whose dominant factor is that of plasticity when mixed with water, retains its shape when molded and contains more or less hydrous silicate of alumina.

Kaolinite is the source of plasticity in clays. Plasticity, however, must be regarded as a physicial property and not a chemical one. In its natural state, where it is formed in situ, kaolinite is never plastic. Its plasticity is developed when the mineral is ground to a fine powder and mixed with water. This may take place in nature by being broken up by a running water and carried by the streams and deposited as a reworked product. Where such is the case it is usually mixed with other substnces the mass of which will be plastic in proportion to the amount of kaolinite it contains and also to the fineness of grain.

Kaolinite is a product of the decomposition of feldspar which is found in granites, gneisses and other igneous rocks. Where the feldspathic rocks are exposed at the surface they are attacked by the combined action of air which contains nitric acid, carbon dioxide and moisture, and by acid-laden surface waters. When surface water becomes charged with carbonic acid it forms one of the most destructive agents in decomposing the rocks. It is aided by the action of frost, roots of growing trees and the disrupting forces and strains set up in the rocks by folding, faulting, earthquakes, and other internal dynamic forces. The surface water charged with carbonic acid finds its way into the cracks and crevices of the rocks which gradually yield to the action of these combined agents of destruction. Potash and soda are the first attacked, and the silicates containing these bases

are first to be broken up. The silicates of lime and magnesia are next attacked, then iron silicates, and finally aluminum silicates which are the most indestructible of the compounds.

When feldspar is decomposed the bond which held the rocks together is destroyed and the soluble salts are carried away in solution; leaving behind the silicate of alumina. The amount of quartz and other undecomposed substances carried away by the transported waters will depend on the velocity of the waters and the depth of the decomposition of the rocks. It may thus be seen that the purity of the aluminous minerals in their original state will vary according to the nature of the parent rock and to the mechanical conditions which attend their formation. This process of rock decay is called weathering. The original compounds are thus broken up and new compounds are formed. The breaking up of the old and the formation of the new compounds require untold ages and by this process the various clays as we now find them have been formed.

CLASSIFICATION OF CLAYS AS TO ORIGIN.

From the foregoing discussion it will be seen that clays may be classified as to origin under two general heads, residual clays and transported clays.

RESIDUAL CLAYS.—Residual clays are those that have been formed by the alteration and decomposition of rocks on which they rest. The purest form of residual clay is kaolin. Instances have been found where kaolinization has taken place to a depth of 100 feet, but this is an exceptional case. On steep slopes the clay will be removed as rapidly as formed. Even fragments of the original rock may be carried down the slopes and deposited with the clay mass and later decomposed forming small bodies of pure clay in the less pure mass.

The purity of the residual clay depends on the character of the original rock, and the thoroughness of the decomposition. If the original rock is a compound of feldspar and quartz and the kaolinization has been complete the result is a mixture of kaolin and quartz. In most clays there will be more or less sand, feldspar, mica, iron in some form, and other less important minerals.

Residual clays are also formed from the weathering of limestones, argillaceous shales and some clayey sandstones. In the case of limestones the calcium and the magnesium carbonates and the iron oxides are dissolved out and carried away by the acidulated waters leaving behind the insoluble clay compounds, sand and chert. The bonding materials of sandstones and shales are broken up by the weathering agents, and where conditions are favorable thick deposits of clay may result

TRANSPORTED CLAYS.—By far the largest clay deposits are those which result from the breaking up of residual deposits by running waters and are carried down the slopes and deposited in bodies of still water. The fine particles of clay are the first to be taken up by the running streams leaving behind the heavier particles of sand, undecomposed mica and feldspar. The distance these sediments are carried depends on the grade and the velocity of the stream. A stream having a velocity of one-third of a mile an hour is sufficient to carry the minute particles of clay, but will not affect the sand and heavier particles. A stream with sufficient velocity to carry small fragments of rock will carry a large amount of clay particles. A slight decrease in velocity will result in dropping the heavier materials, and with a complete loss of velocity even the finest particles will settle to the bottom. Each sudden rise of the stream will carry the mass a little farther until it reaches its final resting place where the particles arrange themselves according to their specific gravity. The heavier fragments are dropped near the shore, while the finer particles are often carried far out into the body of water where beds of almost pure clay accumulate.

MARINE CLAYS.—Marine clays are those which have accumulated on the continental shelf or in deep sea water adjacent to some land area. Near the shore, where the waters are likely to be much disturbed and shallow, the deposits will be largely coarse materials. The finer particles of clay will be carried out into deeper, still water. Vast deposits are thus formed, but owing to the fact that some streams traverse a region of igneous rocks, and others come from a region of sedimentary rocks there will be a wide variation in marine deposits. Later beds of an entirely different character may cover

the older deposits to a depth of hundreds and even thousands of feet. The enormous pressure of the overlying deposits will cause the clays to merge into shales and the sands into sandstones.

Some later orogenic movements of the earth's crust may gradually lift the bottom of the ocean above the surface and in many instances the overlying rocks are eroded leaving the shale beds exposed to the surface.

A slate is a metamorphosed shale. The change has been accompanied by physical forces or compression which may have completely obliterated the original deposition planes and a lamellar structure developed, and by a chemical reaction which has more or less expelled the chemically combined water, thus changing it from a soft plastic material to a hard, rock-like substance.

ESTUARINE CLAYS.—Clays that have been formed in compartively long narrow arms of the sea are known as estuarine clays. They are usually basin-shaped in form. Where streams enter the estuary from the side the clays may be very impure. Clay particles carried by streams of low velocity entering the estuary from the end would be carried out into the quiet water and deposited leaving the coarser materials near the mouth.

LACUSTRINE CLAYS.—These clays are formed along the shores and on the bottoms of lakes. Most of the clays of this type are found in glaciated regions and owe their origin to glacial deposits which have been carried by streams entering some lake or inclosed basin. They are found in basins which have been completely filled with sediment or lifted above the bottom of the lake subsequent to the deposition of the clay.

GLACIAL CLAYS.—Closely associated with the lake clays is a type known as glacial clay. Vast quantities of rock-flour ground and transported by glaciers have been deposited in irregular sheets over large areas in northern regions. The clay deposits thus formed are very irregular in form and in composition.

ALLUVIAL CLAYS.—Extensive clay deposits occur along the flood plains of large rivers. These vary from the stiffest gumbos to the lean sandy clays. The tough gumbo and "buckshot" clays of the Yazoo delta and other large streams owe their plasticity to the fineness

of the clay particles which have been reworked many times by the streams. They are always found out in the inter-stream areas where the currents were sluggish. The coarser particles were dropped near the main channels: the finer clay particles were held in suspension longer and were dropped farther from the channels.

Streams flowing from a glaciated region carrying the finely-ground rock-flour have formed extensive deposits called loess. These deposits were formed during the breaking up of, and immediately following, the glacial period when the streams were flowing at a much higher elevation than at present. In many places the loess is of such even texture that the stratification lines are not discernable. However, there are certain lines of demarkation between the lower and upper divisions indicating that it has been transported and deposited by streams.

AEOLIAN CLAYS.—Some of the loess clays of the west have been carried and redeposited by winds. The adobe clays of the plains are doubtless of this class.

CLASSIFICATION OF CLAYS AS TO USE.

In attempting to make a satisfactory classification of clays as to use one is soon aware of the difficulty in arranging a group that does not include parts of other groups.

There is a wide variation in clays both as to their chemical composition and physical properties. Some clays are worthless when used alone, whereas by combining them with other clays they thereby become some of the most valuable clays. This is especially true of the highly refractory flint clays. The classification of clays according to their uses cannot be made entirely free from overlaps, since about 90 per cent or more of the finished products are a combination of two or more clays and the same clay may be used for different purposes. A more or less arbitrary classification that will serve the purpose of this report will be made.

STRUCTURAL CLAYS.—This type includes the most impure sandy clays used in common building brick to the highly decorative tiling.

There are two essential points to be considered in making a popular structural material from clays. The

first is to get a clay that will burn to a good strong ware, and the second is to get a uniform color. For common building brick red is the most popular color, which ordinarily is obtained from clays containing 4 to 6 per cent of ferric oxide.

The more expensive cream and buff-colored bricks may be obtained by using a low grade refractory clay containing a small amount of iron, or from a clay containing more or less lime. The famous Milwaukee buff-colored brick is burned from clay containing over 15 per cent of lime which neutralizes the 4 per cent of iron oxide the clay contains.

Shales, in some instances mixed with other clays, enter very largely into the construction of ornamental and encoustic tile, paving brick, terra cotta, copings, roofing tile, etc. They are usually high in fluxing properties, which cause them to vitrify into a strong body at a comparatively low temperature.

POTTER'S CLAYS.—Clays used in the manufacture of chinaware, stoneware and earthenware may be designated as potter's clays.

China and porcelain wares are made from high-grade plastic clays, from kaolin or a mixture of two or more of these materials. A glaze or slip which burns to a vitreous transparent body is applied to the outside and inside surfaces. Most of the wares of this kind used in the United States were formerly imported from England, Europe, China and Japan. In recent years, however, New Jersey, Pennsylvania, Ohio, and other States have developed quite an industry in this line.

Clay used in the manufacture of ordinary jugs, jars, churns, milk pans and such wares are usually white to gray in color before being burned, and should be plastic so they can be easily shaped by the potter's hand. They should be moderately refractory and burn to a firm body with little shrinkage. Clays used for this purpose are found in abundance in the Coal Measures and in the unconsolidated sands and clays of the Cretaceous and the later formations.

REFRACTORY CLAYS.—Refractory clays are those that are capable of standing a high degree of temperature without injury to the burned ware. A clay that fuses under 3,000 degrees F. would not be considerd a

high grade fire clay. The manufacture of refractory wares has become one of the most important branches of the clay industry. These products have taken the place of fire-resisting stones and iron pots and have made possible the enormous production of steel and iron, glass ware, electrical appliances and coke.

Clays of this class must contain only a small percentage of iron, potash, soda, lime and magnesia. In the high grade flint clays of the Olive Hill district the total amount of fluxing impurities runs as low as one-fourth of one per cent. It is not uncommon to find the total amount of fluxing materials in a large number of these clays below one per cent.

The most common products made to stand a high degree of heat are, fire bricks, crucibles, glass pots, gas retorts, saggers, fire backs, locomotive linings, stove linings, and tuyeres.

Refractory clays are separated into two classes based on their physical structure; these are plastic clays and flint clays.

The plastic clays may be as refractory as the flint variety, but its plasticity and fineness of grain give it a greater shrinkage on burning than the flint clays. Where the amount of abrasion is small and great heat is required, as in the bottom of a blast furnace, the proportion of flint to plastic is about 3 to 1. Near the top where the abrasion is great and the amount of heat relatively small the proportions are reversed.

It is a very common thing in the Olive Hill district to find the plastic and flint varieties in the same bed. The flint clay generally occurs below and the plastic above, although the reverse is true in some mines.

MISCELLANEOUS CLAYS.—Clays are also used as a food adulterant, water filters, pestles, mortars, models of various kinds, door knobs, fence posts, railroad ties, ink bottles, smoking pipes, emery wheels, paper filling and sizing, playing marbles, pedestals, flower pots, urinals, wash stands, paints, majolica. They form an important part in the manufacture of Portland cement; and are burned as a ballast for road construction.

CHEMICAL PROPERTIES OF CLAYS.

Perhaps there is no other single natural product that is so varied in its chemical composition as clay. In its purest state it is composed of 46.3 per cent of silica, 39.8 per cent of alumina, and 13.9 per cent of water. However, in the process of breaking up of the residual clay and transportation to the deposits as we most commonly find them it assimilates a large number of impurities. A careful analysis of an ordinary clay will show the following chemical constituents:

CHEMICAL CONSTITUENTS OF CLAY.

	Chemical Symbol.
Silica	SiO_2
Alumina	Al_2O_3
Ferric oxide	Fe_2O_3
Lime	CaO
Magnesia	MgO
Potash	K_2O
Soda	Na_2O
Lithia	Li_2O
Titanic acid	TiO_2
Sulphur trioxide	SO_3
Carbon dioxide	CO_2
Water	H_2O

In commenting on the chemical analysis of clays, Messrs. Heinrich Reis and Joseph Keele* give the following:

"There are two methods of quantitatively analyzing clays. One of these is termed the ultimate analysis, the other is known as the rational analysis.

"THE ULTIMATE ANALYSIS: In this method of analysis, which is the one usually employed, the various ingredients of clay are considered to exist as oxides, although they may really be present in much more complex forms. Thus, for example, calcium carbonate ($CaCO_3$), if it were present, is not expressed as such, but instead it is considered as broken up into carbon dioxide (CaO_2) and lime (CaO), with the percentage of each given separately. The sum of these two percent-

*Memoir No. 24-E, Canada Department of Mines, Geological Survey Branch, 1912.

ages would, however, be equal to the amount of lime carbonate present.

"Altogether too much weight is attached to the chemical analysis by those unfamiliar with the properties and behavior of clay and many wholly unwarranted deductions are made from it. It is true that the chemical analysis indicates the percentage of different substances present in the clay, and that the effect or action of these substances is understood in a fairly definite way, but their effectiveness depends to a large degree on their uniformity of distribution, and this is not indicated by the analysis.

"Moreover, the ultimate analysis gives us little or no information regarding certain physical properties, such as plasticity, degree of shrinkage in drying and burning, density after burning, etc.

"It is, therefore, more or less absurd to conclude from a chemical analysis alone that a clay could be used for certain classes of ware.

"But regarding the matter from a fair and conservative standpoint, it would seem that the following inferences may be made from an ultimate chemical analysis, provided the clay is of fine-grained uniform texture, and the elements in it evenly distributed, and not forgetting that there may be numerous exceptions to every case:

"(1) The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities present. High grade clays often show a percentage of silica, alumina, and chemically combined water, approaching quite closely to kaolinite.

"(2) The approximate refractoriness of a clay; for other things being equal, a clay with high total fluxes is commonly less refractory than one with low total fluxes. Several factors, it must be remembered, such as texture, irregularity of distribution of the constituents, and condition of kiln atmosphere may affect the result.

"(3) The color to which the clay burns. This must be judged with extreme caution. Assuming the constituents to be evenly distributed, then a clay with 1 per cent or less of ferric oxide is likely to burn pure white, but at high temperatures titanium, if present, appears

to produce discoloration. One with 2 to 3 per cent ferric oxide is likely to burn to buff, and one with more than this will probably burn red, if there is not an excess of lime or alumina present.

"(4) Excess of silica. A high percentage of silica (80 to 90 per cent) may indicate a sandy clay, and possibly one of low shrinkage, but it does not necessarily indicate plasticity. High silica in a fire clay usually shows moderate refractoriness, provided it is evenly distributed.

"(5) Carbon. This should be determined, as it causes trouble in burning if present to the extent of several percent, requiring thorough oxidation in firing before the clay is allowed to pass to the vitrifying stage.

"(6) Sulphur trioxide. Since this may be the cause of swelling in improperly burned wares, and also indicate the presence of soluble sulphates, it should also be determined.

"(7) The presence of a high percentage of lime carbonate shows the clay to be of calcareous character, and if this is evenly distributed it is likely to be of buff-burning character, with low refractoriness, and a narrow margin, between vitrification and viscosity.

"(8) Titanium dioxide should be determined in fire clays, as 2 or 3 per cent may reduce the refractoriness to an appreciable degree.

"Rational Analysis.—In this method of analysis an attempt is made to determine the compounds actually present in a clay, such as kaolinite, quartz, feldspar, etc. The methods thus far developed are unsatisfactory."

MINERALS FOUND IN CLAYS AND THEIR EFFECTS ON THE BURNED WARE.

Under the microscope, many of the mineral constituents contained in clays may be recognied. Some are recognizable with the use of a small magnifying glass and some of the larger particles may be seen with the unaided eye. The more common minerals are kaolinite, pholerite, silica, feldspar, mica, siderite, pyrite, hematite, calcite, gypsum, magnesium and titanium. Some exceptional clays contain lithia, ammonia, maganese,

alum, rutile, zircon, tourmaline, muscovite, hydrargyllite (gibbsite), barite, copper and chromium.

As stated above a pure clay is composed of silica, alumina, and water. All the other constituents usually found in clays would be considered impurities. There are two classes of impurities found in clays. One is composed of minerals that are beneficial and the other is a combination of minerals that are injurious to the clays. What is considered an impurity in one clay, however, would not be considered an impurity in another clay. The common fluxing minerals in clays that are to be burned would not necessarily be injurious in clays used in the manufacture of paper. The purpose for which a clay is to be used will, therefore, determine the minerals that are detrimental impurities and those that are essential impurities.

KAOLINITE.—Kaolinite has long been recognized as the base of clays. It is a hydrous silicate of alumina ($Al_2O_3 2SiO_2, 2H_2O$) and contains 46.3 silica, 39.8 alumina and 13.9 water. Under the microscope it is made up of minute white scales. It has a specific gravity of 2.4 to 2.63. It is considered infusible.

PHOLERITE.—Pholerite is also a hydrous aluminum silicate, with physical properties very similar to that of kaolinite. The following analysis of pholerite shows it to be somewhat higher in alumina than kaolinite:

	Per cent.
Silica	39.3
Alumina	45.0
Water	15.7

The base of many of the high refractory clays of Carter and Greenup Counties, Kentucky, is composed of pholerite and kaolinite as shown by the analyses given in this report. Its presence may be recognized when the ratio of the combined silica to the alumina is less than 1.16.

SILICA.—Silica, in ordinary clays, is the most abundant mineral, and occurs in greater or less quantities, in all clays. It may be present in the form of the uncombined silica or quartz or in the combined form of one of the many silicates.

Where it is present as quartz or sand, the color may be transparent or stained by iron oxides. The grains may be sharp or well rounded by abrasion in being transported by water.

The chemical formula for quartz is $Si\ 0_2$ and has the composition of 46.7 silica and 53.3 oxygen. In the uncombined state, silica is fused at about 3,326 degrees F. Combined with other minerals, the fusion point may be greatly reduced. The presence of sand in clays increases the refractoriness and decreases the shrinkage, the plasticity and the tensile strength.

FELDSPAR.—Feldspar is a silicate of alumina found in abundance in igneous rocks, especially granite. It is decomposed by carbonated waters and is not, therefore, as abundant in clays as quartz. It has an anti-shrinkage effect on clays and fuses at about 2,192 degrees F. When combined with other fluxes it may fuse at a much lower temperature.

IRON.—Iron that occurs in clays may be divided into two classes, (1) the brown or red-burning or ferric salts, such as limonite, hematite and pyrite; and, (2) the dark-burning ferrous salts such as siderite, chlorite and augite. Iron in some form and in some quantity is found in all clays. It is found abundantly in the red burning clays; and the white burning clays generally contain the smallest amount. It may be present as minute crystals too small to be seen without the aid of a magnifying glass, as thin, irregular bands, or segregated into concretions of various shapes and sizes.

Iron is usually regarded as nature's great coloring agent. It is the most general source of reds and browns in clay wares and in combination with other minerals; or in very small quantities it may produce the light buff and cream colors. The very popular speckled brick may be the result of finely divided particles of pyrite evenly distributed through the clay. Its presence is a very essential property in producing the red color in paving and building bricks, terra cotta and drain tile. Maganese also produces the same result.

The color of clay or shale depends, to a large extent on the amount of iron and the condition in which it is present and on the neutralizing effect of other minerals. The unoxidized iron, such as pyrite, siderite, magnetite

and a few less common forms, as long as it remains unchanged, gives little or no color to the raw clay. In the presence of oxygen the ferrous salt may change to some form of ferric salt which will give a red or a brown color to the clay. Some clays and shales owe their red color to the presence of organic matter.

While iron is an important factor in coloring the raw clay, it exerts a still greater influence on the ware in burning. The effect of iron on the burned ware depends on four factors, (1) the amount of iron present in the raw clay; (2) the control of the heat; (3) the intensity of the heat; and (4) the presence of neutralizing agents. Two of these factors, 1 and 4, in a given clay, would be constant, but the kind of heat used and the intensity of the heat would determine the color of the burned ware. The effects of the different forms of iron on the burned ware are given below in the discussion of each of the iron compounds. Iron is also a very important factor in lowering the fusion point of clays. Its presence in refractory clays is, therefore, detrimental unless it is in very small amount and thoroughly distributed, or is neutralized by the presence of lime, oxide of cobalt, feldspar or quartz.

Limonite is found widely distributed in clays and shales. It has the chemical formula of 2 Fe_2O_3, 3 H_2O, and contains 59.8 per cent of iron, 25.7 per cent of oxygen, and 14.5 per cent of water. It may occur as a thin coating on grains of sand and other particles; as thin bands through the clay; or, as irregular concretions of varied sizes. It is largely derived through alteration of iron sulphides and carbonates. Under the action of heat it loses its combined water and is changed to hematite. It is one of the principal sources of brown and red colors.

Hematite is the anhydrous sesquioxide of iron and occurs less frequently in clays than limonite. Its chemical formula is Fe_2O_3 and is composed of 70 per cent of iron and 30 per cent of oxygen. It imparts a red to reddish-brown color to shales and clays in which it is found. When heated to redness limonite is converted to hematite so that the two produce the general body-color to the burned ware.

Pyrite is a sulphide of iron ($Fe S_2$) with the composition of 46.6 per cent of iron, and 53.4 per cent of sulphur. It is very common in unweathered clays and shales and in certain forms is known by the miners as "sulphur balls," "shiners," etc. It has a bright metallic lustre and may be present as small rosette crystals or in some form of iron concretions or nodules.

Pyrite is readily converted to limonite in the presence of oxygen and moisture. If lime is present the iron sulphide changes to the hydroxide and the sulphur trioxide may unite with the carbonate of lime to form gypsum.

When pyrite is subjected to heat in the presence of oxygen the iron becomes iron oxide and the sulphur takes up oxygen and becomes sulphur dioxide or sulphur trioxide.

Pyrite acts as a flux in clays and greatly reduces the fusion point. It may be unequally distributed through the clays in crystals or particles large enough to be easily removed by hand picking or by washing. If it is in very small particles and is freely disseminated through the clays it will fuse on the ware, producing a brown or black spotted variegated surface which is very popular on face bricks.

Mica in some form is found in a large number of clays. Muscovite, the white variety and biotite, the dark variety are the two common forms in which it is found. In all sedimentary clays it is found in very small scales.

The fusion point of mica is so high that it rarely effects the color of common brick clays, but its presence in refractory clays is detrimental because of the presence of iron.

Siderite is the carbonate of iron ($Fe C O_3$) and is composed of 62.1 per cent of iron protoxide and 37.9 per cent of carbon dioxide. It is often found in shales and unweathered clays in the form of iron clay-stones, or more uniformly distributed in the form of crystalline particles, or perhaps as a thin film over other substances. Siderite is more frequently found in unweathered sedimentary shales on the carboniferous rocks, though it sometimes occurs in weathered surface clays. If it is in a finely comminuted condition and uniformly dis-

tributed through the clays it gives a gray slate color to the mass.

When clays containing siderite are exposed to heat, the carbon dioxide is driven off at a temperature of about 1,296 degrees F. Some writers claim it is not all removed under 1,652 degrees F. The dark green color of some wares may result from the iron oxide uniting with silica forming a ferrous silicate which gives a green color.

There are other forms of iron found in some clays, but their presence is generally so rare that they will only be mentioned here.

Magnetite is a magnetic iron that may be detected in the clay and removed by the use of a magnet. It is rare in most sedimentary clays, but may occur more commonly in residual beds.

Marcasite is a disulphide of iron and has the same chemical composition as pyrite. It weathers out of a clay very quickly where the clay is exposed to air and moisture.

Ilmenite is an oxide of iron and titanium and is found in some sedimentary and residual clays and shales. It may occur as small dark grains, as crystals or as small plates.

Glauconite, biotite, hornblende and garnet are complex silicates of iron. Some of these on exposure to the air in the presence of moisture are changed to limonite. They all fuse at a low temperature and act as strong fluxes on clays in burning.

CALCITE.—Lime or calcite is a very common mineral that is found widely distributed in nature. Its chemical formula is $Ca\ C\ O_3$ and is composed of 56. per cent of lime and 44. per cent of carbon dioxide or carbonic acid.

Lime may be present in clays in the form of carbonate, as calcite or dolomite; as a sulphate in the form of gypsum; or in the form of a silicate as chlorite, feldspar and mica.

The presence of the carbonate may be easily detected by the application of a few drops of strong vinegar or dilute hydrochloric acid which will set free the carbon dioxide in a strong effervescence. It requires warm hydrochloric acid to detect the presence of dolomite. Calcite may be present in clays in particles too small to be seen without the use of a magnifying glass, or it may

occur in irregular concretions which are very objectionable if allowed to remain in the clays. Lime in this form combines with free silica and iron to form silicates which fuse at a low temperature. Unless the heat is continued long enough for all the lime to combine with silica, some of it will remain as calcium hydrate or quick lime, which will cause the ware to swell and break when exposed to the weathering agents.

The sulphate of lime or gypsum is not as common in clays generally as the carbonate form, but some clays contain large amounts of it. It may occur as thin, white plates in cracks in the clay or as long pencil-like crystals. Gypsum is so soft that it can be scratched with the finger nail.

In burning clays containing gypsum it may cause a white crust known as "salt peter" to form on the walls of the kilns. At a temperature of 250 degrees F., gypsum loses its combined water and forms plaster of Paris. At a still higher temperature it gives up its sulphuric acid.

The silicates of lime are the most complex forms in which lime is found in clays. The most common forms are the feldspar group, the chlorite group, the mica group and the hornblende group. It should be noted that the orthoclase feldspar does not contain lime.

Lime, in whatever form it occurs in clays, acts as a flux in lowering the fusion point. It is more powerful when it occurs in the form of a silicate. The presence of lime in clays has a bleaching effect on the ware. Some clays contain 4 to 6 per cent of iron oxide and would naturally be expected to burn to a red color, but on account of the presence of 15 to 18 per cent of lime, the clay burns to a buff or cream color. It has an anti-shrinkage effect on clays in burning.

MAGNESIA.—Magnesia (Mg O) occurs in clays in three forms; silicates, carbonates, and sulphates. The source of magnesia in clays is usually from the decomposition of magnesian limestone, or dolomite; or it may result from the decomposition of iron sulphide. It is not found as generally distributed in clays as lime.

Its influences on clay wares in burning is very similar to that of calcium carbonate, except that the fluxing

property of the magnesia is slightly less than that of lime.

CARBON.—The presence of carbon in clays may be a source of trouble in burning the ware. It prevents or checks the oxidation of any iron that may be present until all the carbon is consumed. The combustion of the carbon takes place, according to Ries, between 1,472 degrees and 1,652 degrees F. Unless the temperature is held in this limit until all the carbon is consumed, the surface of the ware may become fused mitigating against the further escape of inclosed gases and causing in bricks what is known as "black coring." Clays that are porous and are burned with a good supply of air in the kiln when the temperature reaches a good red heat will be free from black cores.

TITANIUM.—Titanium oxide ($Ti\ O_2$) is present in small quantity in nearly all clays. The particles are so small, however, that they can be seen only by the use of the magnifying glass. It occurs as ilmenite and rutile. In small quantities titanic acid is usually regarded as a negative impurity, but where the clay contains 4 to 6 per cent it has a fluxing effect when raised to white heat.

ALKALIES.—There are two alkalies that are common in practically all clays. These are potash (K_2O) and soda (Na_2O). The chief source of alkalies in clays is from orthoclase feldspar, a silicate of alumina from which potash may be derived, and oligoclase, a lime-soda feldspar. Glauconite or greensand and muscovite contain potash. Garnet, hornblende, and some other rare minerals may also be the source of alkalies in some clays.

Alkalies have a powerful effect in lowering the fusion point of clays. They are most effective in the form of soluble salts. They are an advantage in paving brick clays as the clays are fused into a hard mass, at a low temperature, thereby affecting a saving in fuel and time. In clays intended for refractory purposes, the smaller the percentage of alkalies, the better.

WATER.—Water is present in clays (1), as mechanically combined water or moisture, and (2), as chemically combined water.

MECHANICALLY COMBINED WATER OR MOISTURE.—The amount of mechanically combined water in clays varies

from about 2 per cent in air-dried clay to as much as 35 per cent in plastic mud. The amount of water vapor a clay will absorb depends on the physical character of the clay. All clays are more or less porous and will absorb water until all of the little spaces between the clay particles are completely filled. Fine-grained clays absorb more moisture than coarse-grained clays for the reason that the capillary attraction is greater in the former than in the latter. In very coarse-grained clays the water runs out as readily as it runs in, while the little capillary tubes of fine-grained clays will absorb the water and hold it.

Clays that are capable of absorbing and holding a large amount of water require more water to render them plastic than lean clays. A clay will absorb moisture from the air when the air is more saturated than the clay. If the air becomes dryer than the clay, the transfer of moisture takes place between the clay and the air.

When clays are made into bricks or other wares, they lose a large per cent of the mechanically held water in air drying. The entire amount of this water, however, is only parted with at a temperature of 212 degrees F. If the water is removed from a fine-grained fat clay too rapidly in drying there is danger of the ware cracking. In some clays, and especially those that are made porous by the application of grog or calcine, the moisture may be driven off by artificial heat at a very rapid rate without injury to the texture of the clay.

Care should be used in drying clays containing alkalies and other injurious minerals held in solution. On rapid drying, according to Ries, the solutions will be evaporated leaving the compounds on the surface to give trouble later in burning.

CHEMICALLY COMBINED WATER.—As above stated, all of the moisture or mechanically held water in clays is driven off on heating them to a temperature of 212 degrees F. However, when this is done, there still remains from 4 to 15 per cent of water which is in chemical combination with the clay. This water is not entirely driven off until a temperature of a red heat is reached.

Fine-grained clays contain a much larger percentage of chemically combined water than sandy clays.

When a clay loses its chemically combined water its most potent factor, plasticity, is forever destroyed. No amount of grinding or addition of water can restore this once active property. It is only by the loss of plasticity and water, however, that it becomes the hard durable ware that is capable of withstanding the hard service to which burned clay wares are subjected.

PHYSICAL PROPERTIES OF CLAYS.

It is generally understood by all writers on ceramics that the physical properties of clays are far more essential than the chemical properties. It is the physical property more than the chemical property that determines the range in which a clay is applied. As an illustration, in the Olive Hill district there are two distinct varieties of clays found in the same bed. Both are highly refractory and have practically the same chemical composition, but the uses to which they are applied are based on their physical properties. One is very plastic and the other is of a flint variety.

PLASTICITY.—That property which enables a clay, when mixed with a certain percentage of water, to be molded into any desired shape and to retain that shape when dry is called its plasticity. It is this property that has made possible the great development of all branches of the ceramic industry.

As has been stated above, the amount of water necessary to render a clay plastic depends on the character of the clay. Some close-grained clays require twice as much water to render them plastic as a coarse clay.

SHRINKAGE.—The decrease in volume a clay undergoes in air drying is known as air-shrinkage. When heated to red heat they suffer another loss in volume called fire-shrinkage.

The air-shrinkage is due to the loss of moisture or hydroscopic water. All clays require more or less water to render them plastic. The large percentage of added water fills the pores of the clay and the individual particles are forced apart.

It is in this swollen condition that clays are generally molded into the various forms they are expected to retain when burned. A certain per cent of the water is removed on air drying the ware, the shrinkage being in proportion to the amount of water evaporated. The entire amount of water vapor is not removed until the ware is heated to 212 degrees F. It is readily seen, therefore, that the air-shrinkage does not correspond to the total loss of mechanically held water or moisture.

The air-shrinkage of some clays is accompanied by a cracking of the ware. Some highly plastic clays like gumbo crack very badly and have a high degree of shrinkage. Some refractory plastic clays like those of the Olive Hill district can be dried very rapidly without injury.

In a large number of clays sand, grog, calcine and other substances are used to decrease the shrinkage. Calcine is largely used in the manufacture of the Olive Hill fire brick on account of its refractoriness and low shrinkage property.

All clays contract to a greater or less degree in burning. The shrinkage is not complete until all of the chemically combined water and other volatile matter are removed and all of the pores of the ware are closed resulting in complete vitrification.

Some of the refractory clays of the Olive Hill district expand to a certain degree in burning. The bricks containing a large percentage of calcine and flint clay and only enough plastic clay to bond them have a very low shrinkage.

TENSILE STRENGTH.—Tensile strength is usually defined as "the resistance that a clay offers to the rupture or being pulled apart." The resistance is least in a freshly molded clay. It increases greatly when the clay is air-dried and reaches the maximum amount when the clay is vitrified.

The tensile strength of a clay determines the care that must be exercised in handling the green wares; and also the amount of calcine, grog or other non-adhesive substances that may be introduced into the clay ware.

An aggregation of clean sand has no tensile strength. Introduce into it enough plastic clay to form a paste and let it dry and it will offer more or less re-

sistance when pulled apart. There seems to be some relation between plasticity and tensile strength, but it does not necessarily follow that a clay high in plasticity will possess a high tensile strength. Some substances like limestone have a high degree of tensile strength but are entirely wanting in plasticity.

FUSIBILITY.—The adaptability of a clay to withstand heat involves practically all of the physical and the chemical properties the clay may possess. The behavior of a clay under certain heat conditions largely determines its degree of usefulness. This involves color, shrinkage, hardness and degree of heat used.

All clays as they are used in the ceramic arts are fusible at some temperature. The point at which this takes place depends on (1) the chemical character and (2) the physical conditions of the clay. A clay containing a large percentage of kaolinite, silicate of alumina, and practically free from fluxing impurities is a high-fusing or refractory clay. With this as a base, by the admixture of other clays of known physical and chemical properties, any desired ware may be produced.

A clay undergoes three changes in passing from a solid to a molten mass. These are incipient fusion, vitrification, and viscosity. The respective temperatures at which they take place vary with each clay, depending on the nature and the amount of fluxing impurities present, the fineness of the grain, and the nature of the flame in the kiln.

Incipient vitrification takes place when individual grains are lost. It is then very hard and shrinks but little after this point is reached. A further rise of temperature of 150 degrees to 500 degrees F. is sufficient to produce a greater softening of the clay completely uniting all of the individual grains, but the clay still retains its shape. At this point it ceases to contract. If the heat is removed at this point the ware will be vitrified. If the heat is raised to a sufficient temperature above this the ware swells and becomes a viscous or molten mass.

The control of the heat in burning a kiln of clay products is of vital importance to the clay manufacture. In some clays it is necessary to raise the temperature to a certain point and hold it there for some time to effect

certain chemical changes or to allow the escape of certain gases. A slight increase in the temperature at this critical time may produce a premature vitrification of the surface of the ware thereby enclosing sulphur and unconsumed carbon and prevent further oxydation. At still higher temperatures carbon monoxide and hydrocarbon gases develop and become very active agents of destruction.

In some clays the temperature interval between incipient fusion and complete viscosity is very little and it is important to know at what temperature each takes place; and knowing these to be able to control the heat and the air supply at the crucial point.

Several methods have been devised by which the conduct of a clay at high temperatures may be studied and its fusion point determined. Some are based on the shrinkage of the clay, color of the flame, chemical analysis giving the quantitative relation of pure clay to the fluxing ingredients, and thermo-electric resistance. In most of these the results are more or less unreliable and subject to a wide variation, since they largely depend on the experience of the operator.

SEGER CONES.—These consist of certain definite mixtures of clay-base and fluxes whose fusion points are established and have been extensively used for determining the temperature of kilns. There were only 36 cones in the original Seger series, but additions have been made by Cramer and others until now there is a series of 61 numbers ranging from 022 to 39. The fusion point of 022 is 1,094 degrees F., and 3,470 degrees F. for cone 39. The variation in the fusion points of cones 022 to 010 is 54 degrees F., whereas between cones 010 and 39 the difference is only 36 degrees F.

COMPOSITION AND FUSING POINTS OF SEGER CONES

No. of Cone	Composition.			Fusing Point.	
				Degrees F.	Degrees C.
0.022	0.5 Na_2O 0.5 PbO	——	2.0 SiO_2 1.0 B_2O_3	1,094	590
0.021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1,148	620
0.020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1,202	650
0.019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1,256	680
0.018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1,310	710
0.017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1,364	740
0.016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1.0 B_2O_3	1,418	770
0.015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1.0 B_2O_3	1,472	800
0.014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1.0 B_2O_3	1,526	830
0.013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1.0 B_2O_3	1,580	860
0.012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1.0 B_2O_3	1,634	890
0.011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1.0 B_2O_3	1,688	920
0.010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	1,742	950
0.09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.45 B_2O_3	1,778	970
0.08	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.60 SiO_2 0.40 B_2O_3	1,814	990
0.07	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.65 SiO_2 0.35 B_2O_3	1,850	1,010
0.06	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.70 SiO_2 0.30 B_2O_3	1,886	1,030
0.05	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.75 SiO_2 0.25 B_2O_3	1,922	1,050
0.04	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.80 SiO_2 0.20 B_2O_3	1,950	1,070
0.03	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.85 SiO_2 0.15 B_2O_3	1,994	1,090
0.02	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.90 SiO_2 0.10 B_2O_3	2,030	1,110
0.01	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.95 SiO_2 0.05 B_2O_3	2,066	1,130
1	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	4 SiO_2	2,102	1,150
2	0.3 K_2O 0.7 CaO	0.1 Fe_2O_3 0.4 Al_2O_3	4 SiO_2	2,138	1,170

COMPOSITION AND FUSING POINTS OF SEGER CONES CONTINUED.

No. of cone.	Composition.	Fusing Point. Degrees F.	Fusing Point. Degrees C.
3	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ $\left\{\begin{array}{l}0.05\ Fe_2O_3\\0.45\ Al_2O_3\end{array}\right\}$ 4 SiO_2	2,174	1,190
4	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.5 Al_2O_3— 4 SiO_2	2,210	1,210
5	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.5 Al_2O_3— 5 SiO_2	2,246	1,230
6	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.6 Al_2O_3— 6 SiO_2	2,282	1,250
7	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.7 Al_2O_3— 7 SiO_2	2,318	1,270
8	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.8 Al_2O_3— 8 SiO_2	2,354	1,290
9	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 0.9 Al_2O_3— 9 SiO_2	2,390	1,310
10	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 1.0 Al_2O_3— 10 SiO_2	2,426	1,330
11	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 1.2 Al_2O_3— 12 SiO_2	2,462	1,350
12	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 1.4 Al_2O_3— 14 SiO_2	2,498	1,370
13	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 1.6 Al_2O_3— 16 SiO_2	2,534	1,390
14	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 1.8 Al_2O_3— 18 SiO_2	2,570	1,410
15	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 2.1 Al_2O_3— 21 SiO_2	2,606	1,430
16	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 2.4 Al_2O_3— 24 SiO_2	2,642	1,450
17	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 2.7 Al_2O_3— 27 SiO_2	2,678	1,470
18	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 3.1 Al_2O_3— 31 SiO_2	2,714	1,490
19	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 3.5 Al_2O_3— 35 SiO_2	2,750	1,510
20	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 3.9 Al_2O_3— 39 SiO_2	2,786	1,530
21	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 4.4 Al_2O_3— 44 SiO_2	2,822	1,550
22	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 4.9 Al_2O_3— 49 SiO_2	2,858	1,570
23	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 5.4 Al_2O_3— 54 SiO_2	2,894	1,590
24	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 6.0 Al_2O_3— 60 SiO_2	2,930	1,610
25	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 6.6 Al_2O_3— 66 SiO_2	2,966	1,630
26	$\left\{\begin{array}{l}0.3\ K_2O\\0.7\ CaO\end{array}\right\}$ 7.2 Al_2O_3— 72 SiO_2	3,002	1,650

COMPOSITION AND FUSING POINTS OF SEGER CONES. CONTINUED.

No. of cone.	Composition.	Fusing Point. Degrees F.	Fusing Point. Degrees C.
27	$\left\{\begin{matrix} 0.3 & K_2O \\ 0.7 & CaO \end{matrix}\right\}$ 2.0 Al_2O_3—200 SiO_2	3,038	1,670
28	.... Al_2O_3—10 SiO_2	3,074	1,690
29	.... Al_2O_3—8 SiO_2	3,110	1,710
30	.... Al_2O_3—6 SiO_2	3,146	1,730
31	.... Al_2O_3—5 SiO_2	3,182	1,750
32	.... Al_2O_3—4 SiO_2	3,218	1,770
33	.... Al_2O_3—3 SiO_2	3,254	1,790
34	.... Al_2O_3—2.5 SiO_2	3,290	1,810
35	.... Al_2O_3—2 SiO_2	3,326	1,830
36	.... Al_2O_3—1.5 SiO_2	3,362	1,850
37	....	3,398	1,880
38	....	3,434	1,910
39	....	3,470	1,940

REPORT ON THE TECHNOLOGY OF KENTUCKY CLAYS, INCLUDING CHEMICAL AND MECHANICAL ANALYSES, AND BURNING TESTS.

BY H. D. EASTON, E. M.

INTRODUCTORY REMARKS.

Clay has been used in the manufacture of brick, pottery and other products since the dawn of the earliest civilization. So widely distributed on the face of the earth is this mineral, and so abundant and varied in character (color, form and physical properties) are these deposits, that it is not surprising that it has such an enormously extensive application and that every State and Territory in the Union finds clay and clay products to be a source of much wealth.

The great importance of clay is shown by the fact that the products of the clay-working industries marketed in the United States during the year 1911, had a value of $162,236,181 (counting only the clay products and not that mined). This was a decrease of 4.63 per cent as compared with 170,115,974 in 1910, and a decrease of 2.46 per cent as compared with $166,321,213 for 1909.

The value of the clay products of Kentucky for the years 1908-1911, as given by the Mineral Resources of the United States, was as follows:

Year.	Brick and tile.	Pottery.	Total.
1908	$2,085,460	$153,684	$2,239,108
1909	2,332,475	146,397	2,478,872
1910	2,418,116	149,421	2,567,537
1911	2,254,000	114,094	2,368,094

For the United States during this period the value was:

Year.	Brick and tile.	Pottery.	Total.
1908	$108,062,207	$25,135,555	$133,197,762
1909	135,271,772	31,049,441	166,321,213
1910	136,331,291	33,784,678	170,115,974
1911	127,717,621	34,518,560	162,236,181

This shows a decrease of 7.77 per cent for Kentucky and a decrease of 4.63 per cent for the whole United States for the year 1911 as compared with 1910.

In 1911 Ohio ranked first in the output of clay products, having a value of $32,663,895 or 20.13 per cent of the total for the United States: then followed, in the order named, Pennsylvania with a value of $20,270,033, New Jersey with a value of $18,178,228, and Illinois with a value of $14,333,011. Kentucky ranked fourteenth with 1.46 per cent of the total product for the United States which was practically the same standing held by Kansas.

The following table shows the kinds, quantity, value etc., of the clay products of Kentucky from 1905 to 1911, inclusive, the data being taken from the Mineral Resources of the United States:

	1905	1906	1907	1908	1909	1910	1911
Brick:							
Common—							
Quantity	147,702,000	142,185,000	143,731,000	110,545,000	119,183,000	115,890,000	107,771,000
Value	$862,330.00	$881,879.00	$932,469.00	$687,365.00	$741,115.00	$743,732.00	$692,378.00
Average per M	5.84	6.20	6.49	6.22	6.22	6.42	6.42
Vitrified—							
Quantity	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Value	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Average per M	$14.27	$14.13	$14.27	$13.26	$12.69	$12.74	$12.37
Front—							
Quantity	11,558,000	11,893,000	7,926,000	11,067,000	11,626,000	10,238,000	8,972,000
Value	$128,777.00	$109,771.00	$86,568.00	$119,785.00	$104,022.00	$99,532.00	$90,330.00
Average per M	11.14	9.23	10.92	10.82	8.95	9.72	10.07
Fire ..... value	739,059.00	898,527.00	940,415.00	770,221.00	899,363.00	955,557.00	890,810.00
Draintile ..... value	28,865.00	27,359.00	32,723.00	53,308.00	53,213.00	66,217.00	64,005.00
Sewer pipe ..... value	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Fireproofing, etc. value	....	(a)	(a)	$7,236.00	(a)	(a)	(a)
Tile, not drain..... value	$296,949.00	$296,391.00	$255,054.00	215,000.00	$296,179.00	$318,966.00	$292,563.00
Pottery:							
Red earthenware value	22,674.00	26,637.00	27,546.00	23,448.00	20,225.00	10,004.00	12,880.00
Stoneware, etc. value	134,409.00	140,572.00	139,075.00	130,200.00	126,172.00	139,417.00	101,214.00
Miscellaneous ..... value	193,287.00	211,287.00	197,514.00	232,518.00	238,583.00	234,112.00	223,914.00
Total value	$2,406,350.00	$2,592,423.00	$2,611,364.00	$2,239,108.00	$2,478,872.00	$2,567,537.00	$2,368,097.00
Number of operating firms reporting	121	117	115	116	99	95	96
Rank of State	10	11	11	12	14	14	14

(a) Included in "Miscellaneous."

The foregoing figures do not show the wealth of clay possessed by this State, but they merely indicate the present development in the manufacture of clay-products. When we consider the leading clay-producing States in 1911, Kentucky stands fifth in both quantity and value and showed the greatest increase of all the States during that year. This increase was chiefly in fire clay, being 63.90 per cent in tonnage and 47.64 per cent in value. New Jersey ranks first in quantity and value of clay produced, with Pennsylvania second, they having held this relative rank for several years. In both of these States fire clay is the leading variety. Ohio was third in quantity and fifth in value of clay produced although she stood first as a clay-working State. Missouri was fourth in quantity and third in value.

Although Kentucky has a clay-working industry of considerable importance and ranks high as a clay-producing State, yet she possesses an abundance and variety of clays that are but little known. The future of this State in the production of clay and clay-products is very bright and it is the object of this bulletin to emphasize this fact and, by pointing out the character of some of these clays, help in the commercial utilization of these deposits.

CHAPTER 1.

WHAT IS CLAY?

The word clay, like the word fire, has a more or less definite meaning to all persons of ordinary intelligence; clay is such an abundant, and commonly met-with, part of the earth that nearly all men are familiar with it. Clay and sand make up the greater part of all soil, and the one is known almost as well as the other. Both are found scattered over the earth, and the floor of the sea, and this wide range of distribution, with an ever changing proportion and great variety of composition, gives every man ample opportunity to know each.

POPULAR DEFINITION OF CLAY.

The most popular definition of the term clay is: Earthy materials which become plastic, or pasty, when

mixed with water and, owing to this property of becoming pasty (plasticity) can be molded into a great variety of shapes which are retained when the clay is dried; when heated to redness, or higher, the clay becomes hardened and stone-like, thus holding the useful or ornamental form given before firing.

While it is true that some clays are lacking in plasticity, yet this predominant characteristic is the most important property. If, in the definition of clay, plasticity alone be taken as the distinguishing characteristic, then some very important clay deposits would be thrown out; hence this definition needs to be modified by a consideration of other properties.

SCIENTIFIC DEFINITION OF CLAY.

Clay is a mineral mixture the base of which is kaolinite. Strictly speaking, the term clay applies solely to the single mineral kaolinite, which is not an original constituent of the earth's crust, but a result of kaolinization (or weathering) of rock containing feldspar.

The term kaolinite, which refers to a mineral, should not be confused with kaolin (or china clay) which refers to a residual clay, usually pure white, and often called china clay. Kaolinite is a hydrous silicate of alumina; chemically it is expressed, Al_2O_3, $2SiO_2$, $2H_2O$ in the proportion of 39.8 per cent of alumina, 46.3 per cent of silica and 13.9 per cent of water. The water in kaolinite is chemically combined with silicate of alumina.

ORIGIN OF CLAY.

Eternal change is going on over the earth's crust: building up here and disintegrating there, with molten rock from inside the earth flowing out at places and solidifying by cooling. The particles of disintegrated rocks are collected by water, wind or glaciers into layers which may again solidify into rock, this formation being called sedimentary rock. The molten magma exuding from the interior of the earth, or being near the surface, cools and forms igneous rock. Corals, crinoid stems, etc., collect in the sea and produce a rock composed chiefly of calcium carbonate, known as limestone. Each of these formations may be altered by heat and pressure, such as is

produced by folding and twisting, as in the case of mountain ridges, nto metamorphoric rock. Again, each of these classes of rocks, sedimentary, igneous, limestone and metamorphic, may be broken up and altered, and this change may produce deposits of clay.

The agents that cause this disintegration act slowly but they have power to dissolve the firmest rocks. The atmosphere, with its moisture, oxygen, carbon dioxide, movements and change of temperature; the action of moving water and ice; the soil, adding to its water the acid products obtained from the decomposition of vegetable matter; all combined, act upon the rocks with a slow, but irresistable power that causes them to decompose and disintegrate.

The crystalline igneous rocks that are found in the earth, or near the surface, represent the source of nearly all other rocks (limestone being an exception). It is by the action of the agencies named above that igneous rocks and limestones supply the materials for sandstones, shales and clays that are classed as sedimentary.

The igneous rock that decomposes most rapidly is granite containing feldspar. Granite is composed of quartz, feldspar and hornblende with other minerals in varying relative amounts. The carbon dioxide of the atmosphere acts upon the potash feldspar and forms carbonate of potash and silicate of alumina. The carbonate of potash is soluble in water and is removed by the percolating waters, leaving clay behind; this clay is a mixture, then, of the silicate of alumina and the other insoluble materials of the parent rock. By the foregoing we see that there necessarily must be a very great range in the varieties of clay, since there is a base of silicate of alumina and varying proportions of rock fragments (representing all stages of weathering), lime, iron, mica, quartz and many other substances.

The origin of clay will be discussed more fully in the following pages under the origin of Kaolin—the more nearly pure deposits of our clay base (silicate of alumina), having the name kaolin given to it.

KAOLIN.

Kaolin, or China Clay, finds its most important utilization in the manufacture of white ware and porcelain. The white color and refractoriness of these is due to kaolin, but they are not made of kaolin alone; with the kaolin is mixed ball-clay, to supply plasticity, the kaolin being deficient in this physical property; quartz is added to diminish the enormous shrinkage of the kaolin; and, as a fluxing material, feldspar, or calcined bones, is used.

We have defined kaolin under the scientific definition of clay. As stated before, it is usually white, contains little or no iron oxide and generally contains a large proportion of the mineral kaolinite. Henrich Ries, in his book, "Clays; Occurrence, Properties and Uses,"* says:

"There are clays made up almost entirely of other hydrous aluminum silicates than kaolinite, which are also termed kaolins, as the Indianaite of Indiana, or the Halloysite of Alabama.

"A deposit of pure kaolinite has not thus far been found in nature, though some very nearly pure occurrences are known. While the term kaolin is sometimes applied to any residual clay, the writer believes that this designation should be restricted to white-burning residual clays, a usage which is wide-spread but has not become universal. The name *kaolin* is a corruption of the Chinese *Kauling,* which means *high ridge,* and is the name of a hill near Jauchau Fu, where the mineral is obtained.

"In this connection it is interesting to note that, according to Richthofen, the rock from which King-te-chin porcelain is made, is not true kaolin, but a hard jade-like greenish rock which occurs between beds of slate. He states: 'This rock is reduced, by stamping, to a white powder, of which the finest portion is ingeniously and repeatedly separated. This is then moulded into small bricks. The Chinese distinguish chiefly two kinds of this material. Either of them is sold in King-te-chin in the shape of bricks, and as either is a white earth, they offer no visible differences. They

*Clays; Occurrence, Properties and Uses, by H. Pies, P. 8, 1906.

are made at different places, in the manner described, by pounding hard rock, but the aspect of the rock is nearly alike in both cases. For one of these two kinds of material the place Kaoling ('high ridge') was in ancient times in high repute, and, though it has lost its prestige since centuries, the Chinese still designate by the name 'Kaoling' the kind of earth which was formerly derived from there, but is now prepared in other places. The application of the name by Berzelius to porcelain earth was made on the erroneous supposition that the white earth which he received from a member of one of the embassies (I think Lord Amherst) occurred naturally in this state. The second kind of material bears the name Pe-tun-tse ('white clay')."

"The following analyses* show the average composition of (I) the natural material from King-to-chin, such as is used in the manufacture of the finest poreclain; (II) that from the same locality used in the so-called blue Canton ware; (III) that of the English Cornwall stone; (IV) washed kaolin from St. Yrieux, France; and (V) washed kaolin from Hockessin, Del.

	I.	II.	III.	IV.	V.
Silica (SiO_2)	73.55	73.55	73.57	48.68	48.73
Alumina (Al_2O_3)	21.09	18.98	16.47	36.92	37.02
Ferric oxide (Fe_2O_3)	....	....	.27	....	.79
Lime (CaO)	2.55	1.58	1.17	....	.16
Magnesia (MgO)	.15	1.08	.28	.52	.11
Potash (K_2O)	....	.46	5.84	.58	.41
Soda (Na_2O)	....	2.09			.04
Water (H_2O)	2.62	1.96	2.45	13.13	12.83
Total	99.62	99.70	99.98	99.83	100.00

The above analyses show a most striking difference between the two washed kaolins and the Chinese clay and Cornwall stone.

ORIGIN OF KAOLIN.

While some six or seven theories have been advanced to explain the origin of kaolin, yet the oldest and most commonly accepted is that feldspathic rocks,

*G. P. Merrill, Non-Metallic Minerals, P. 224, 1904.

through a process of weathering, have formed these beds in situ. Such mechanical agents as frost, changes of temperature, percolating water, etc., have brought about a disintegration of the parent rock and the grains of feldspar have decomposed into a white mass which is chiefly made up of a hydrated silicate of alumina, Al_2O_3, $2SiO_2$, $2H_2O$, called kaolinite.

Orthoclase feldspar, or common feldspar, the parent rock from which kaolins are formed, is a double silicate of alumina and potash (K_2O, Al_2O_3, $6SiO_2$). The mechanical agencies are greatly aided by oxygen and carbon dioxide in weathering this complex feldspar: the percolating waters carry the oxygen and carbon dioxide to all parts of the feldspar through cracks and crevices formed by frost, change of temperature, and other agencies, causing it to form less complex compounds through a process of decay. Some of the salts are transformed into soluble minerals and are carried away in solution, potassium changing to the carbonate and being removed as such. The alumina and silica combine with water and remain behind as kaolinite.

Although numerous objections have been raised to the theory of kaolinization by weathering, yet there are some very weighty facts to substantiate this theory.*

1. The possible alteration of feldspar to kaolinite by water, whether containing carbon dioxide or not.

2. The observed transitition with depth of kaolin into unweathered parent rock in many cases. This is seen in the feldspar deposits of North Carolina, Maryland, Pennsylvania, Delaware, and Massachusetts.

3. The fact that in the United States practically all of the commercially valuable kaolin deposits lie south of the glaciated areas; in other words, in a region in which residual clays still remain, is singificant.

Some of the other theories accounting for the decomposition of feldspathic rocks and the formation of kaolin are as follows:

1. Kaolinization by Water from Swamps and Peat Bogs. When water seeps through carbonaceous matter, such as is present in swamps, it picks up carbonic acid, organic matter, etc., and, being deficient in oxygen, it

*Henrich Ries, Trans. Am. Cer. So., Vol. XIII, P. 57.

attacks the parent rock and forms kaolin. While it is wholly possible that some deposits owe their origin to this process, there are but few deposits that show any certainty of such water as being the agent of decomposition of the parent rock.

2. Kaolinization by Pneumatolysis or Volcanic Emanations. This theory attributes the decomposition of the parent feldspathic rock to the action of hot water or gases given off by an igneous mass. It is doubted that any deposits of kaolin of commercial value have been formed by the action of magmatic water.

Another theory somewhat similar to this is that ascending spring water (cold) charged with carbon dioxide has caused the kaolinization in some cases.

MUSCOVITE AS THE SOURCE OF KAOLIN.

Each of the above theories consider that kaolin has originated from feldspar, but the theory has been advocated that the parent mineral is sericite instead of feldspathic rock. Sericite is of the same composition as muscovite, but is made up of white flakes so very small that it has no mica appearance except when in a mass. This muscovite may represent an intermediate step in the decomposition of feldspar and this intermediate product (muscovite) then forms kaolin. However, this theory has little to support it.

The weight of opinion favors feldspar as the source of kaolin and weathering as the process of formation, granting that acidulated swamp water and volcanic waters, and vapor, might be the agents in some cases.

ORIGIN OF KENTUCKY KAOLIN.

In Bulletin No. 6, of the Kentucky Geological Survey, Dr. James H. Gardner gives a discussion of the origin of the Kentucky kaolin deposits of Hart county. The presence of fossils in the kaolin beds, together with the laminated condition of the deposits, led to the "opinion that the majority of the clays in the district are of marine origin, having been carried probably by rivers from a great distance, first into the prongs of the Lower Carboniferous sea and then quickly deposited as local sediments at the bottom."

Speaking of the lamination of these deposits, Dr. Gardner said: "* * * they often show very distinct and well marked layers—distinct in color, in physical nature and in chemical composition. This is a characteristic that we would expect to find only in sedimentary deposits."

Continuing the quotation: "Another important feature in connection with some of the white clay deposits of Hart county is the fact that they are underlaid by a thin stratum of Chester coal, which itself rests upon a typical under-clay (so called 'fire-clay'). It would seem that the close relation of the clay deposit above with the coal and under-clay below is more in accord with the theory of sedimentation than with that of replacement. After the coal was formed, the clay must have been deposited in the comparatively shallow water which followed a slow submergence. However, such a relation could be brought about by uncomformity." * * * "On the other hand, some of the clays by association and resemblance seem very much as if they were the result of replaced chert. The deposits, however, are found outcropping entirely around the hills, as if laid down in regular horizontal layers and afterwards exposed by erosion; although it is yet to be determined, definitely, whether they do exist through the hills or whether they are rim deposits."

Dr. Gardner now informs me that these clay deposits feather out into the conglomerate as has been shown by exposures made in tunneling. This conglomerate is made up of quartz pebbles ranging in size up to that of a small hen's eggs with an occasional boulder of considerable size. He is now of the opinion that these clay deposits owe their origin to the weathering of feldspar in the conglomerate since practically no feldspar is found in the conglomerate at the surface, whereas it is present deeper down.

MECHANICAL AND CHEMICAL ALTERATIONS OF CLAYS SUBSEQUENT TO THEIR DEPOSITION.

The same chemical and mechanical agents that produced clay deposits continue in a greater or less degree of activity and often alter or destroy the deposits after they are formed. The mechanical agents are continually

altering the earth's crust by uplifting, folding and twisting and these displacements and other movements are often seen to have acted upon clay deposits. The clay deposit may be moved into such a position as to favor erosion; again, the reverse may take place and the clay deposit become deeply buried.

The chemical agents may alter the deposits by leaching, softening, consolidating or by changing the color. While a clay deposit may have portions of different color due to a difference in chemical composition of the original clay, yet the process of oxidation may rust out the iron compound and produce tints of yellow or brown.

CHAPTER 2.

CLASSIFICATION AND USES OF CLAY DEPOSITS.

Geologists classify clays according to their origin, while the classification given by some of the clay technologists is based upon the uses to which the different clays are put, or upon the chemical and physical properties. Other classifications are based upon the chemical and mineralogical composition.

The difficulty of making a satisfactory classification is shown by the fact that quite a number of these classifications are to be found in nearly all of the clay reports published by the various State Geological Surveys. The most common ones are as follows:

Basing his classification on the composition, Professor Edward Orton* gives the following:

	Character.	Uses.
High-grade clays. (50 per cent or more kaolin with silica.)	1. Kaolin.†	Manufacture of fine ware.
	2. China-clay.	Manufacture of fine ware.
	3. Porcelain-clay.	Manufacture of fine ware.
	4. Fire-clay (hard.)	Refractory materials.
	5. Fire-clay (plastic.)	Refractory materials.
	6. Potters' clay.	Earthenware, etc.
Low-grade clays. (10 to 70 per cent kaolin with notable per cent fluxing elements.)	1. Argillaceous shale.	Paving block, etc.
	2. Ferruginous shale.	Pressed brick, etc.
	3. Siliceous clays.	Paving block and sewer pipe.
	4. Tile-clays.	Roofing tile, drain tile.
	5. Brick-clays.	Pressed brick, ornamental brick.
	6. Calcareous shales.	Common brick.

Speaking of the above divisions, Professor Orton states: "The first division comprises all clays and shales that contain in conjunction with not less than fifty per cent of kaolin base little else but the finely divided silica. The amount of fluxing elements are in all cases small, rarely aggregating as much as five per cent, and generally falling below three per cent. Oxide of iron constitutes much the largest single element of these fluxes. In almost every case the potash is low. Such a division as is here suggested would leave out some highly re-

*Ohio Geol. Survey, Vol. VII, part 1, P. 52.
†Kaolinite is meant here instead of kaolin.

fractory clays, it is true, but the good properties of such would seem to result principally from the silica they contain."

"The second division includes all ordinary clays and shales. They may range in kaolin base from ten to seventy per cent, but they always carry a notable percentage of the fluxing elements. The alkalies generally make two to five per cent, while lime, magnesia and iron add two or three times as much. Coarse sand and rock fragments often make a conspicuous part also. These low qualities of the clay more frequently result from a surplus of fluxing element than from a deficiency in kaolin base."

In the following scheme by Messrs. S. W. Beyer and I. A. Williams*, which, in the main, is the classification offered by Prof. Edward Orton, of Columbus, Ohio, the subdivisions are somewhat more extensive, and, while the ultimate basis is that of origin, the physical and chemical properties are taken into account in making some of the lesser subdivisions."

- Primary or residual clays.
  - Entirely decomposed feldspathic rock.
    - Kaolin or China clay.
  - Partially decomposed feldspathic rock.
    - English Cornwall stone.
    - Porzellan Erde of the Germans.
- Secondary or transported clays.
  - Deposited in still water.
    - Fire clays.
      - Highly refractory.
        - Flint fire clay.
        - Plastic fire clay.
      - Moderately refractory.
        - No. 2 fire clay.
        - Stoneware clay.
        - Sewer pipe clay.
    - Shales.
      - Indurated. Not metamorphosed.
        - Slaty shales.
        - Bituminous shales.
        - Clay shales.
  - Deposited from running water.
    - Alluvium.
    - Sandy clays.
    - Loam.
  - Deposited by glacial action.
    - Leached.
      - Whitish or red bowlder clay.
    - Unleached.
      - Blue bowlder clay.
  - Deposited by winds.
    - Loess.

*Iowa Geol. Survey, XIV, P. 40.

Prof H. A. Wheeler, in his report on the clays of Missouri*, gives a classification based on the purposes for which each clay is to be used. His classification follows:

1. White ware	Kaolin. China clay. Ball clay.
2. Refractory	Plastic fire clay. Flint clay. Refractory shale.
3. Potters'	Plastic clay and shale of moderate fusibility.
4. Vitrifying	Paving brick clay and shale. Sewer pipe clay and shale. Roofing tile clay and shale.
5. Brick	Common brick clay and shale. Terra cotta clay and shale. Drain tile clay and shale.
6. Gumbo	Burnt ballast clay.
7. Slip	Clays of very easy fusibility.

The unsatisfactory feature of the above classification lies in the fact that a certain clay might, and often does, have a number of uses not included under one class.

GRIMSLEY'S CLASSIFICATION.†

I. Residual clays.
 1. Kaolin.
 2. China or porcelain clay.

II. Transported clays.
 (A) Refractory (fluxing impurities low.)
  3. Flint fire clay.
  4. Plastic fire clay.
 (B) Semi-refractory (fluxing impurities medium.)
  5. Paving brick clay and shale.
  6. Sewer pipe clay and shale.
  7. Roofing tile clay and shale.
  8. Stoneware clay.
 (C) Non-refractory (fluxing impurities high.)
  9. Pottery clays.
   (a) Ball clay.
   (b) Flower pot clay.

*Missouri Geological Survey, ,Vol. XI, P. 25.

†Mr. G. P. Grimsley, W. Va. Geol. Survey, Vol. III, p. 70, 1906, also quoted by Mr. Solon Shedd in Clays and Clay Industry of Washington, p. 11, 1910.

10. Brick and tile clay and shale.
    (a) Ornamental brick clay and shale.
    (b) Terra cotta clay and shale.
    (c) Ornamental tile clay and shale.
    (d) Common brick and tile clay and shale.
11. Gumbo ballast clay.
12. Slip clay.

The above classification of clays is based on their origin and subdivided according to their uses as determined by chemical and physical properties.

LADD'S CLASSIFICATION.*

Indigenous.
- (A) Kaolins.
  - (a) Superficial sheets.
  - (b) Pockets.
  - (c) Veins.

Foreign or transported.
- (A) Sedimentary.
  - (a) Marine.
    1. Pelagic (deposited in deeper water.)
    2. Littoral (deposited near shore.)
  - (b) Lacustrine (deposited in fresh water lakes.)
  - (c) Stream.
    1. Floodplain.
    2. Delta.
- (B) Meta-sedimentary.
- (C) Residual.
- (D) Unassorted.

Reis† comments upon this classification as follows: "Under the Indigenous are included those clays formed by the decay of feldspar and other aluminous silicates in place. The Foreign or transported embrace all sedimentary deposits. The Meta-sedimentary clays are chemical products resulting from the decomposition of other transported materials, such as volcanic tuffs, pumice, etc. The Residual clays include the insoluble residue left by the dissolving of limestones, while under unassorted are included the glacial ones."

"The term kaolin, as here used, includes all residual clays, except those derived from limestones, and, since it is not restricted to white-burning ones, its use is un-

*Mo. Geol. Survey, XI, p. 25. 1897.
†Clays, Occurrence, Properties and Uses, by Ries, p. 25, 1906.

fortunate. Furthermore, the placing of limestone residuals in a separate class seems a rather fine distinction. Delta clays hardly seem of sufficient importance to warrant being placed in a separate class, and are rare."

RIES' CLASSIFICATION.*

Ries states that a classification based on origin is perhaps the best, since it, of necessity, takes the form of deposit into account.

I. Deposited in water.
 (a) Marine clays or shales. Deposits often of great extent.
  White burning clays. Ball clays.
  Fire clays or shales. Buff burning.
  Impure clays or shales. { Calcareous. / Non-calcareous.
 (b) Lacustrine clays. (Deposited in lakes or swamps.)
  Fire clays or shales.
  Impure clays or shales, red burning.
  Calcareous clays, usually of surface character.
 (c) Flood plain clays.
  Usually impure and sandy.
 (d) Esturine clays. (Deposited in estuaries.)
  Mostly impure and finely laminated.
II. Glacial clays, found in the drift, and often stony.
 May be either red or cream burning.
III. Wind-formed deposits (some loess).
IV. Chemical deposits. (Some flint clays.)

While no classification can be made that will prove satisfactory in every particular, owing to the fact that there is no sharp line of separation between different grades of clays, but rather a gradual grading and overlapping both chemically and mineralogically, yet the last classifiaction given above seems to be the most useful from the standpoint of both the technologist and the practical clay-worker. The action of chemical and mechanical agents upon a clay deposit subsequent to its formation, as pointed out in the preceding chapter, shows why this absence of a sharp line of demarcation between the different clays is wanting.

*Md. Geol. Survey, IV, p. 267 and amplified in his book on Clays, p. 27.

USES OF CLAY.

The many uses to which clay is put is shown by the following table which was compiled originally by R. T. Hill,* and amplified by Ries:†

DOMESTIC.—Porcelain, white earthenware, stoneware, yellow ware and Rockingham ware for table service and cooking; majolica stoves; polishing brick, bath brick, fire kindlers.

STRUCTURAL.—Brick, common, front, pressed, ornamental, hollow, glazed, adobe, terra cotta, glazed and encaustic tile, drain tile, paving brick, chimney flues, chimney pots, door knobs, fire proofing, terra cotta lumber, copings, fence posts.

HYGENIC.—Urinals, closet bowls, sinks, washtubs, bath tubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks.

DECORATIVE.—Ornamental pottery, terra cotta, majolica, garden furniture, tombstones.

MINOR USES.—Food adulterants, paint fillers, paper filling, electric insulators, pumps, fulling cloth, scouring soap, packing for horses' feet, chemical apparatus, condensing worms, ink bottles, ultramarine manufacture, emery wheels, playing marbles, battery cups, pins, stilts and spurs for potter's use, shuttle eyes and thread guides, smoking pipes, umbrella stands, pedestals, filter tubes, caster wheels, pump wheels.

REFRACTORY WARES.—Crucibles and other assaying apparatus, gas retorts, fire bricks, glass pots, blocks for tank furnaces, saggers, stove and furnace bricks, blocks for fire boxes, tuyers, cupola bricks.

ENGINEERING WORKS.—Puddle, Portland cement, railroad ballast, water conduits, turbine wheels.

By far the greater portion of the clay products listed above are made from a mixture of three or more clays, this being especially true of the high-grade wares which require rather close control of color, shrinkage, refractoriness, etc.

CHINA CLAYS.—In the manufacture of porcelain, white earthenware and granite ware a mixture of kaolin,

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*Mineral Resources, U. S. 1891, p. 475.
†Professional Paper No. 11, Clays of the U. S. East of the Miss. River, 1903, p. 36. Used by Shedd in Clays of Washington, 1910, p. 89, also by Snyder in Clays of Okla., 1911, p. 87

ball clay, feldspar and quartz is used and these must be of a high-grade and white-burning. The white-burning ball clay supplies the plasticity which is lacking in the kaolin, while the feldspar and quartz counteracts, or reduces, the great shrinkage of the kaolin.

KAOLIN.—In addition to the uses just given for kaolin, it is used in the manufacture of paper, floor tile, wall tile, also in slips, glazes, etc. It is usually washed before using.

Our kaolin deposits are found in the Eastern part of the United States (Connecticut, Pennsylvania, Tennessee, North Carolina, Missouri), being scattered from Vermont to Texas.

Analyses of Some United States Kaolins.

	I	II	III	IV	V	VI	VII
Moisture (H_2O)	2.39	2.71	2.99	0.25	2.05	....	....
Ignition	12.68	16.69	14.80	....	....	....	....
Silica (SiO_2)	48.09	42.32	43.31	62.40	45.78	46.28	46.50
Alumina (Al_2O_3)	34.66	36.92	37.90	26.51	36.46	36.25	37.40
Ferric oxide (Fe_2O_3)	0.78	0.62	0.32	1.14	0.28	1.644	0.80
Ferrous oxide (FeO)	....	....	....	....	1.08	....	....
Lima (CaO)	0.27	0.21	0.23	0.57	0.50	0.192	tr.
Magnesia (MgO)	0.23	0.08	0.13	0.01	0.04	0.321	....
Potash (K_2O)	0.74	0.47	0.25	0.98	0.25	1.69	1.1
Soda (Na_2O)	0.30	0.18	0.12			0.85	
Titanic oxide (TiO_2)	0.25	tr.	0.10	....	....	....	....
Water (H_2O)	....	....	....	8.80	13.40	13.535	12.49
Total	100.39	100.25	100.18	100.66	99.84	100.763	98.29

I. Hart County, Ky., Anal. by Dr. A. M. Peter, Ky., Agri. Expt. Sta.
II. Ibid. I. and II. unwashed. I. from Philip Moss place, II. from same.
III. Ibid. Unwashed from S. J. Murry place.
IV. Webster, N. C. Crude kaolin. N. C. Geol. Surv. Bull. 15, p. 62. 1897.
V. Webster, N. C. Washed kaolin. Ibid.
VI. Brandywine Summit, Pa. Hopkins, Pa. State Coll., App. Rept., 1898-99, p. 36.
VII. West Cornwall, Conn., H. Ries, Clays, Occurrence, Prop., and Uses, p. 168.

BALL-CLAY.—Ball-clays are white burning, highly plastic clays of a sedimentary origin. They usually occur far from the places of origin and are often buried beneath other deposits. They usually have less silica and more alumina than the kaolin. They may be white, brown or of other colors, but they must be white-burning to be of use in the manufacture of porcelain and white ware.

They are found in but few States, and the greater portion of ball clay comes from Tennessee and Florida. Western Kentucky has some very promising deposits of a first class ball-clay. The Florida ball-clay is usually washed before being marketed.

Analyses of Ball Clays.

	I	II	III	IV	V	VI
Moisture	1.36	....	....	....	....	....
Silica (SiO_2)	58.18	46.11	47.26	52.98	56.40	45.97
Alumina (Al_2O_3)	27.82	39.55	35.85	34.26	30.00	36.35
Ferric oxide (Fe_2O_3)	0.64	0.35	1.01	0.40	....	1.08
Ferrous oxide (FeO)	....	....	....	....	....	....
Lime (CaO)	0.30	....	0.58	tr.	0.40	1.14
Magnesia (MgO)	0.30	0.13	0.68	tr.	tr.	1.09
Potash (K_2O)	1.37	....	0.74	1.62	3.26	1.84
Soda (Na_2O)	0.44	....	0.45		2.01	
Titanium oxide (TiO_2)	0.94	1.20	....	....	....	....
Sulphur trioxide (SO_3)	....	0.07	....	....	....	....
Water (H_2O)	9.06	13.78	13.94	11.49	7.93	12.36
Total	100.41	101.19	100.51	100.75	100.00	99.33

I. McCracken County, Ky., by Dr. A. M. Peter, Ky., Agri. Expt. Sta. (No. 25891).
II. Edgar, Fla. U. S. Geol. Surv., Prof. Pap. 11, p. 39, also Ries, Clays Occurrence, Properties and Uses, p. 169.
III. Tenn. Ball from the Mandel-Sant Clay Co., St. Louis, Mo., Am. Cer. So. Trans. Vol. XI, p. 495, by Hereford Hope.
IV. Tenn. Ball No. 1. Am. Cer. So. Trans. Vol. VIII, p. 201.
V. Mayfield, Ky., U. S. Geol. Surv., Prof. Pap. 11, p. 39.
VI. Regina, Mo., Mo. Geol. Surv., XI, p. 566.

FIRE-CLAYS.—A very wide range of clays are known as fire-clays but the term applies chiefly to the highly refractory clays which are free from fluxing materials, such as lime, magnesia, etc. These may be residual or sedimentary and they vary exceedingly in character and in value. They often occur directly beneath coal beds and may be either the plastic or the flint-clay nature. Fire-clays are worked in many States, being widely distributed both geologically and geographically. Kentucky showed an increase of 63.90 per cent in 1911 over 1910 in the tonnage of clay and this increase was almost wholly in fire-clay.

Fire-clays find their most important use in the manufacture of fire-brick and furnace linings. They are also used in the manufacture of glass pots (glass-pot clays come from Germany), crucibles, retorts, terra-cotta,

paving bricks, pressed bricks, etc., there is a very wide range of use for clays that are more or less refractory. Wheeler* gives 2,500 degrees F. as a higher temperature than is used in most operations requiring fire-clay and says that if a clay can be heated to this temperature before it fails or reaches its viscous or scoriaceous vitrification point, it meets the demands of most of the applications of fire-clay. Ries† says that a clay to be considered refractory should not fuse under 3,000 degrees F. (cone 27).

For glass pots, iron and steel furnaces, which are liable to reach higher temperatures than 2,500 degrees F., a more refractory clay must be used. A clay that fails at 2,200 degrees to 2,300 degrees F., may still be successful in places where the temperature never goes above 2,000 degrees F., but in most furnace operations the risk of reaching a temperature of 2,300 to 2,400 degrees F., through carelessness in firing or design, requires the limit to be placed at 2,500 degrees F., to be reasonably sure against accident. This is the temperature of a pure, white heat.*

STONEWARE CLAYS.—The clays used in the manufacture of stoneware are semi-refractory, quite plastic, dense burning and of high tensile strength. In order to permit of turning on a potter's wheel, they need toughness and plasticity. The low grades of stoneware are made from clay that is inferior to the No. 2 fire clay which is the chief clay used in making the better grades. The proper body is made by mixing several clays. The stoneware clays are used in the manufacture of earthenware, yellow ware, art ware, terra-cotta, etc.

SAGGER-CLAYS.—Saggers are vessels of various forms and sizes, in which the high grades of pottery are burned. Quite a variety of refractory and semi-refractory clays are used in making these and they are formed both by hand and by machinery. They are usually sandy and may require other and more plastic clays to hold them together. To have the best sagger mixture coarse grog should be used as freely as can be worked. "A certain proportion of sandy clay with not coarser than

*Mo. Geol. Surv., Vol. XI, p. 133.
†U. S. Geol. Surv., Prof. Pap. 11, p. 40.

10 mesh grains seems to add greatly to the ability to withstand sudden changes of temperature; though a highly kaolinitic mix may be equally good at the beginning, and is possibly more enduring."

TERRA COTTA CLAYS.—A great variety of clays are used to make terra cotta. The most common clay used for this purpose is a semi-refractory, buff-burning clay that will give a dense body at temperatures from 2,250 degrees to 2,350 degrees F. The color of the body is of little importance, but it must be a hard body at the temperature used.

RETORT-CLAYS.—This term is practically the same as stoneware clays.

SEWER-PIPE CLAYS.—Sewer pipe is made from clays that vitrify at temperatures from 2,100 to 2,200 degrees F., burn to a deep red body and have low fire shrinkage. Fine-grained clays or shales containing much iron are used, or a mixture of low-grade fire-clay with shale.

PAVING-BRICK CLAYS.—Same materials used as in the manufacture of sewer-pipe; impure shales are most commonly used.

COMMON-BRICK CLAYS.—Red-burning, low-grade clays that will mold easily and burn hard at temperatures below 2,000 degrees F., are used to make common brick. Almost any kind of clay can be used so long as it will burn at very low temperature.

PRESSED-BRICK CLAYS.—Pressed brick are made from clays that will give a good outline, due to low shrinkage, usually buff in color and of a refractory or semi-refractory character. It is very essential that the color should remain uniform in burning. One of the most promising undeveloped beds of this kind of clay is to be found at the "Chalk Banks" on the Mississippi river, about two miles below Columbus, Hickman County, Kentucky.

SLIP CLAYS.—Slip-clays are those that fuse at low temperatures and give a greenish or brown glaze. The locality from which most of the slip-clay comes is Albany, N. Y.

PAPER-CLAYS.—Clays are used in the raw state for making paper. They must be white and free from grit; the imported wash kaolins are much used.

CHAPTER 3.

CHEMICAL PROPERTIES OF CLAY.

MINERAL COMPOSITION OF CLAYS.

The discussion of the origin of clay, in the preceding pages, indicates the very complex mineralogical character of clays. Clays have a great variety of minerals present, especially so in the case of impure ones. The more nearly pure clays have a less complex character, but never a definite chemical composition. However, a pure clay is often said to be a hydrated silicate of alumina which is written as a definite formula (Al_2O_3, $2SiO_2$, $2H_2O$), being the mineral kaolinite. Some clays do not conform to this formula although consisting chiefly of alumina, silica and water. Wheeler* says that the massive or amorphous variety of kaolinite (called pholerite) constitutes the body or essential constituent in all clays and shales. Other minerals are more or less thoroughly mixed with the kaolinite as impurities. These smaller quantities of associated minerals are among the following: quartz, sand, feldspar, mica, hornblende, various forms of iron, calcite, dolomite, garnet, gypsum, alum, organic matter etc. Moisture is always present. If the impurities cause easy fusibility a small percentage of these may make the clay of little or no value, while other clays with a high percentage of non-detrimental foreign matter such as quartz may be of high value.

CHARACTER OF MINERALS AND THEIR INFLUENCE.

KAOLINITE.

Kaolinite is almost infusible when pure and is the predominating mineral in the purer clays. No absolute pure deposits of this mineral have been found, but the white-burning deposits of kaolin are sometimes nearly so.

Kaolin usually has low plasticity and a tensile strength of from five to fifteen pounds to the square inch. Kaolinite has a hardness of from 1 to 2.5, a specific gravity of 2.4 to 2.6 and a perfect cleavage of thin, transparent crystallized plates.

*Mo. Geol. Survey, Vol. XI, p. 50.

SILICA OR QUARTZ.

This is one of the non-detrimental impurities which may be present in the form of sand; chemically combined with the silicates feldspar, mica, etc.; or chemically combined in the kaolinite. This variety of occurrences indicates that quartz is to be found in all clays, both in residual and sedimentary, being in most cases finer and more rounded in the sedimentary clays. In the free condition, as sand, the silica is sometimes visible. but usually too fine to be seen, in which case it may be detected by grinding it between the teeth; sometimes it is too fine to be detected by the taste.

The chemically combined silica is very variable in amount; in the case of a perfectly pure clay where the silica is combined with the alumina of kaolinite, it constitutes 46.3 per cent of the alumina; or 39.3 per cent, if pholerite is the base.* The amount that may occur chemically combined with such silicates as feldspar, mica, etc., will range from 0.5 to 6.0 per cent in high-grade clays, from 5 to 12 per cent in the fair-grade clays, and from 10 to 25 per cent in the low-grade clays. The quartz grains may be so abundant as to give the clay the appearance of sand, having a low plasticity, requiring very little water to mold it and having a low shrinkage. This low shrinkage is due to the small quantity of water required to work the clay up to the plastic paste; the loss of this mechanically mixed water causes a reduction in volume in drying, while the silica has no influence on the air-shrinkage; the greater the amount of sand present, the less the fire-shrinkage. When the grains of quartz are not too fine the clay may be used for abrasive purposes, as in certain kinds of soap. This free quartz may constitute 35 per cent, or even more, of the clay, but usually from one-fifth to one-third.

Quartz exerts a decided influence on the fusibility of clay, being a refractory agent at low temperatures, but acting as a flux at high temperatures, and thus decreasing the refractoriness, hence it is a damaging factor for the highest refractory clays.

*Wheeler. Mo. Geol. Survey, Vol. XI, p. 53.

TITANIUM DIOXIDE.

Small quantities of titanium dioxide, TiO_2, are found in most clays; the quantity varies from a mere trace to a little over one per cent. This titanic acid is a white compound and is infusible. While large quantities present in clay would act as a flux and be detrimental, yet the small amount that actually occurs is of little or no harm. Titanic acid owes its presence in the clay to the titaniferous iron found in igneous feldspathic rocks which are the parent of clays.

ORGANIC MATTER.

Organic matter settles in the clay at the time of its deposition or comes from the roots of plants that grow in the mud that later formed the clay. It is easily burned out and has very little effect upon the clay other than influencing the original color, being responsible for nearly all the colors except red, brown, yellow and green, which colors usually are imparted by iron. The colors given by organic matter may disguise the presence of iron.

MOISTURE.

Water is chemically combined to the extent of nearly 14 per cent in kaolinite, but the percentage of combined water in most clays is much lower, being anywhere from 5 to 12 per cent, depending upon the proportion of sand present. This moisture is all driven off at a red heat and destroys, permanently, the plasticity of the clay. We shall see later, under the question of plasticity, that this combined water is not what gives clay its plasticity.

Besides the water of hydration, there may be a great deal of water mechanically mixed with the clay. This moisture will evaporate upon air-drying to such an extent as to cause the clay to feel perfectly dry; it requires a temperature of 100 degrees C. to drive off the last of this mechanically mixed water.

MICA.

Mica is present in many clays. It occurs in the form of thin scales or spangles that can be seen by the naked

eye because of their being very bright. The highly micaceous clays are rarely of value for the manufacture of clay ware. All of the several species of mica are silicates of alumina, with other bases, containing from 4 to 12 per cent of potash and soda. The mica is always included, by the commercial chemist, with the alkalies in the feldspar. The most common species are biotite (black mica) and muscovite (white mica).

IRON.

Iron, in some form, is usually present in clays, having a marked influence on both color and fusibility. The chemist, in giving the analysis of a clay, reports two forms, Ferric Oxide (Fe_2O_3) and Ferrous Oxide (FeO).

FERRIC OXIDE.—This form is represented by hematite, limonite, mica and pyrite. The limonite is the most common of these forms in which iron occurs in clay and gives various shades of yellow and brown. Hematite is not so commonly present; it gives the reds and reddish browns in most cases. Pyrite is common in clays from the coal measures and is objectionable in refractory clays as it makes black fused spots. It produces a variegated, unsatisfactory color in most cases.

FERROUS OXIDE.—This form is represented by silicates and carbonates. The mineral siderite is the carbonate of iron and may occur as concretionary masses known as clay-ironstones, or as crystalline grains, or as a film coating other minerals in the clay. It effervesces freely in warm dilute hydrochloric acid, giving a yellow solution. Clays containing siderite are generally of a dark color—blue or slate gray. If not oxidized in burning, the ferrous compounds produce a ware of a dark gray to black color; with slow heating in the presence of air, they may be oxidized into ferric salts and produce colors from buff to brown and bright red.

These ferrous compounds are very detrimental on account of their action as fluxes.

LIME.

Lime, if present as a silicate, is detrimental in refractory clays but as carbonate or sulphate it is not so fluxing. It has a tendency to neutralize the coloring ac-

tion of iron. Lime is present in feldspar, calcite and dolomite and gypsum.

FELDSPAR.—Feldspar is almost always present, along with quartz, in clays. It is a hard mineral, having a pronounced cleavage which tends to cause the fragments to break off in flat surfaces. Orthoclase feldspar is the most common form and is usually pink, red or yellowish in color; the clays coming from granitic rocks contain this form of feldspar. The next most common form is plagioclase feldspar. Feldspar readily weathers and forms clay, especially the plagioclase type.

CALCITE AND DOLOMITE.—These minerals form limestone when massive, and are extremely abundant in clays. Calcite is the carbonate of lime, while dolomite is the double carbonate of lime and magnesia; the latter is less commonly found in clays. Lime, in the form of concretions of these minerals, is very objectionable since it combines with the free silica and iron to form fusible silicates.

GYPSUM.—Lime occurs as a sulphate, in gypsum, in the form of grains, needles, well-formed crystals, or lamellar masses. In this form it is not so active as a flux as when in the other forms.

MAGNESIA.—Magnesia is found in nearly all clays, ranging from a mere trace up to over 6 per cent. It may occur as a carbonate, as in dolomite; as a sulphate, as in epsom salts; or as a silicate, as in mica, chlorite and hornblende. Like lime, it possibly acts as a decolorizing agent in clays containing coloring matter in the form of iron. The quantity is usually too low to have a marked effect.

OTHER MINERALS.—Other minerals, in small quantities, occur in clays and sometimes some of these have a coloring action.

CHAPTER IV.

PHYSICAL PROPERTIES OF CLAYS.

It is the physical properties of clays, rather than the chemical composition, that are the most important factors in determining the uses to which they may be suited. While a chemical analysis sometimes gives positive evidence and often tells what color the burned clay will assume, yet there are times when the analysis is wholly misleading as to the value of a clay. There are clays of very different chemical composition, yet, despite this wide variation, each may be admirably adapted to the same application in the arts. Again, two clays may have nearly the same chemical composition, and yet not be at all equally applicable to the same use.

It is best to test a clay physically without going to the chemist at all unless some special difficulty is met with and some particular information is required as to the chemical composition. In all cases the chemical analysis must be taken merely as a guide pointing to the possible uses to which a clay can be placed, then this must be followed up by the physical tests.

In determining what products may be made from a clay, it is necessary to examine it physically; the most important of these physical properties to be determined are as follows:

Structure.
Hardness.
Color.
Feel.
Taste.
Slacking.
Plasticity.
Tensile Strength.
Shrinkage.
Rate of Drying.
Fineness of Grain.
Fusibility.

STRUCTURE.

The method of mining a clay deposit and the cost thereof will be greatly influenced by the structure of the

clay. Likewise, the method to be used in preparing the clay to be molded and, to some extent, the machinery to be used will be influenced by the structure of the deposit. These questions are of much importance in the economic working of a clay deposit, hence the structure of the clay as it occurs in the bed has a practical bearing.

Ordinarily clay is massive, or structureless; it is an amorphous type of kaolinite which, in the impure form of ordinary clay, is uncrystalline in structure. Clay may occur in such structures as shales where the materials have been subjected to pressure; in this form it has a leaf-like structure. It may occur in a slaty, a laminated or a concretionary structure. Slates have been subjected to enormous pressure which has changed both the chemical composition and the structure: the water of hydration is largely expelled, leaving little or no plasticity. The laminated structure was given the bed during its formation, whereas each of the other forms represent subsequent alterations. The flint clays, which are non-plastic, have a conchoidal fracture, the loess clays have a pronounced vertical jointage, and the fire clays and potters' clays are usually massive. The agent most active in producing these various structures is pressure.

HARDNESS.

Flint clays are often quite hard and, because of this hardness, break with a shell-like fracture (conchoidal). They reach a hardness of 2.5 to 3.5 on the mineralogists' scale. Most clays are much softer than this, ranging below the point where they can be scratched by the thumb nail, say, below 2.0 on the scale.

The importance of hardness is in the burned clay where it gives the clay products power to resist wear, abrasion and chemical action. When clays are burned, the hardness and strength increases very rapidly until the maximum is reached at vitrification. When fully vitrified, most clays reach a hardness that will scratch glass, ranging from 6.0 to 7.5 on the scale of hardness.

COLOR.

Clays have an exceedingly wide range of colors, some of which are well suited to paint-making; these

natural colors range all the way from pure white to a dark blue (almost black) including all the shades of red, yellow, brown, etc. Like hardness, this physical property is of great importance in the burned clay, both as to its value and use. Upon burning, the natural color is almost always changed (the exception being some of the white clays) and the range of colors in the burned clay is not as wide as in the natural material.

Kaolin deposits, when pure, are white, but are often stained red, pink, yellow or brown by iron. Other clays are found white, but this does not necessarily indicate the absence of other impurities than coloring matter. Rocks are so impregnated with iron that pure white deposits of clay are rarely met with: if iron is absent, organic matter is likely to be present in the clay and destroy its white color.

Iron in some form is responsible for the greater part of the red, brown and buff colors in clay, the more iron present the deeper the colors and the darker the colors produced upon burning. The gray to drab colors are usually due to organic matter, which, in a fine state of division, is disseminated through the clay. Organic matter sometimes gives red colors, and, if present in large amounts, it produces the dark slate colors. Organic matter is easily burned out without damage to the clay when it exposes the true color of the ware which it disguised in the natural state.

The natural color of a clay will not be a reliable indication of the color to be expected upon burning, as was just pointed out in the case of organic matter being present. However, if the natural clay is given a red or yellow color by iron, then this will give a red product in all probability; other coloring agents might overbalance this—calcium carbonate, if present in large amounts, might cause the clay to burn a buff color. In burned clay the most common colors are reds, browns, buffs, yellows and white. Only by an actual burning test can these colors be determined and such a test will show a range of colors at different temperatures in most clays: the color will change as a clay advances from a low to a high temperature.

FEEL AND TASTE.

Many clays have an unctious, or greasy feel, which is most pronounced in the finer clays. The non-plastic clays, even when fine and pure, lack this soapy feel. By the feel of a clay some idea of its fineness and plasticity can be acquired. Of all the physical properties of clays, plasticity is the most important, and this can be determined to some extent in the field by the feel. If the clay has a harsh or rough feel, it is a lean (non-plastic) clay, while a soapy feel would indicate a fat (plastic) clay, which could be mixed with water and shaped into desired forms without cracking.

By crushing dry clay between the teeth, the plasticity and the presence of grit can be determined; if the clay is allowed to remain surrounding the teeth for a minute, it will adhere to them with great tenacity in case the clay is fat; but if the clay is lean, it can easily be spit out of the mouth. The teeth form an excellent means of detecting grit that may be present and gives a fair approximation of the size of grains. The taste will show the presence of such soluble impurities as epsom salts, alum, sulphate of iron, etc.

Both taste and feel are of much use in examining a clay and will give a fair idea of plasticity, fineness, grit and at times the presence or absence of soluble salts.

SLACKING.

Slacking is that property possessed by all clays and most shales, of separating or dissolving into small particles or flakes upon being immersed in water. Some clays swell upon being wet and this swelling sometimes causes trouble in maintaining roadways in coal mines having such a clay for a bottom. After swelling, the clay breaks up, more or less rapidly, into small particles and crumbles to pieces; these pieces then disintegrate into finer and finer grains and flakes. Fine-grain clays disintegrate into very minute particles, slowly peeling off from the surface until the whole mass is slacked.

The rate of slacking varies widely with different grades of clay and shale; in some cases prolonged shaking in water is required to cause complete disintegration. This is specially true of very hard non-plastic flint clays.

Two to ten minutes is about all the time required for a cube one inch square to disintegrate, in most cases. The clay must be air-dried before trying to slack it.

Slacking is of much importance in working clays. The more rapidly a clay will take up water and disintegrate, the quicker it can be worked into a satisfactory paste. Slacking gives a means of determining the size of grains in a clay. Rapid slacking aids in washing a clay since the fine particles can easily be stirred up while allowing the coarser ones to settle to the bottom and collect there; the fine particles of clay are then collected by settling in another tank.

Clays are often allowed to weather for long periods before being worked up and used. Repeated drying and wetting is an effective agent in breaking up a clay and this is primarily a slacking process being repeated over and over. After a clay is thus disintegrated by weathering, the rains have opportunity to percolate through the mass and dissolve out and carry away the soluble impurities. Thus a clay exposed to the weather will be somewhat purified and rendered more homogeneous.

PLASTICITY.

When most of the clays are thoroughly mixed with the right proportion of water, they form a paste that enables them to be shaped into desired forms and retain these forms until they are burned. This property is known as plasticity, and is the most valuable property that a clay possesses. There have been many theories advanced to explain this property, but each remains a theory and is of no value to the clay worker.

These various theories are of scientific interest, but they have not reached a point of explaining the property of plasticity in a manner that has any usefulness in determining the manner of controlling this property in clay working.

Plasticity can be determined by testing a clay, but, so far, it is not explained satisfactorily. Clay is about the only mineral substance that possesses much plasticity. A plastic clay, when properly mixed with water into a paste, can be shaped into almost any useful or ornamental form and have strength enough to retain a delicate form until the fire treatment changes it into a

stone-like substance. A clay that is lacking in plasticity (lean) would have very little application in the production of common clay ware; a clay containing a high amount of sand would be low in plasticity. A great range of differing degrees of plasticity exists in clays and no hard and fast rule can be made to apply to this property. It is usually true that the fine-grained clays, free from grit, are the more plastic, while the sandy ones are lean. Among the kaolins are found exceptions since some of them are lean although exceedingly fine-grained. A plastic clay is to be preferred, not only because of the greater ease in shaping and working it, but because it permits the use of more grog (flint, burned clay, etc.) and makes much stronger ware.

Water must be mixed with a clay to bring it into the most plastic condition. If made too wet they work easily but do not retain their shape so well after the ware is formed; if a low quantity of water is used, it becomes difficult to work them up to a uniform condition, but they retain the molded shape much better than if wet over much.

Wheeler* states that the highest degree of plasticity in a coarse clay will require from 14.0 to 20.0 per cent of water added to the air-dried material; with the fine clays, from 20.0 to 25.0 per cent is needed; while the very fine clays, as the kaolin, often require 25.0 to 30.0 and occasionally 35.0 per cent of water. The writer finds that some clays that have been in the laboratory several years, and thus become thoroughly air-dried, require over 40.0 per cent of water to bring them to their most plastic condition.

The following table shows the amount of water required to produce the highest degree of plasticity in the clays of Missouri†:

Loess, or brick clays	16.0 to 19.0 per cent.
Fire and potters' clays	15.0 to 33.0
Flint clays	15.0 to 24.0
Kaolins	18.0 to 35.0
Shales	14.0 to 25.0

*Missouri Geol. Survey, Vol. XI, p. 97.
†Ibid, p. 98.

The percentage of water required to give the maximum plasticity of the Kentucky clays is given in each individual case in the following pages.

HOW TO DETERMINE THE AMOUNT OF PLASTICITY.

Plasticity has not been satisfactorily explained or understood and there is no uniform or standard way of measuring it. The usual manner of working a clay up with water and determining its plasticity by handling and molding it gives no definite standard to go by except for experienced clay workers.

Several ways of measuring the degree of plasticity have been suggested, but the best of these seems to be by determining its tensile strength.

TENSILE STRENGTH.

Tensile strength is the property of a clay that resists its being pulled apart when thoroughly air-dried.

The Kentucky clays herein reported upon were all ground to pass through a 20-mesh sieve (a few to a 30-mesh sieve) and mixed with enough water to make a plastic paste: this paste was then molded into tensile-strength briquettes of the usual form used in testing cement. The clay was added a little at a time and firmly pressed with the thumb until the mold was filled and heaped up; slow filling avoided air bubbles; the ball of the hand was then used to press the clay into a compact mass. A fine steel wire, stretched tight in a frame, was used to cut off the surplus clay even with the mold, and the briquette slipped out. In the case of too sticky clays, the mold was oiled before filling. This gave a briquette with a square inch section at the center which was allowed to dry in the air for several weeks. Each briquette was numbered by using the sharp point of a drawing pencil. When fully dried, the briquettes were tested in a small testing machine and proper correction made for shrinkage; the amount of correction was determined by the shrinkage of the clay as determined by the method to be described under the heading of Shrinkage.

Tensile strength is a very important property of a clay for two reasons. First, a clay having a high tensile strength will be tough enough to permit the green ware

to be handled without breaking or losing its form, and will permit the ware to be stacked up in the kiln without crushing that at the bottom. Second, tensile strength will give a fair notion of the degree of plasticity. However, there are marked exceptions to the rule that tensile strength and plasticity are related. A clay low in tensile strength may be very plastic, or a clay that is not very plastic may possess a high tensile strength.

SHRINKAGE.

When a clay is worked into a paste and allowed to air-dry, it contracts (air-shrinkage) and when burned a further contraction (fire-shrinkage) takes place.

AIR-SHRINKAGE. Air-shrinkage is due to the evaporation of the water used to make the paste. The water holds the particles of clay substance somewhat apart, but upon evaporation the clay grains come into close contact with each other with an attending reduction in volume. These clay grains have interstitial spaces even though the clay is very dry and compact. Upon the addition of water these spaces are filled, the grains slightly separated and a film of water forms between the particles holding them apart so as to increase the volume: upon drying, the reverse action is brought about, producing shrinkage. After the film of water is removed by evaporation so as to allow the particles of clay to come together again, air-shrinkage ceases, but the moisture is not all removed. To drive off all of this water, a temperature of 100 deg. C. must be reached and held for some time.

Water does not form a film so readily in a coarse-grained clay but merely fills the voids between the grains, hence coarse-grained clays shrink but little upon air-drying. On the other hand, the fine-grained clays have much of the film formed and suffer a correspondingly high air-shrinkage. The fine-grained clays are more likely to crack and check in drying than are the coarse-grained ones.

The rapidity with which drying may be done is of much importance since it will be a factor in designing a drying plant. By the addition of grog (burned clay or sand) clays may be dried more rapidly without crack-

ing, and will shrink less. This is due to the same cause that allows coarse-grained clay to dry more rapidly.

FIRE-SHRINKAGE. When clay is heated, an additional shrinkage takes place up to the point of vitrification; this is known as fire-shrinkage. This varies greatly in different clays and ranges anywhere from 2.0 to 20.0 per cent, or even more. Fire-shrinkage begins at a red heat, 1,200 deg. to 1,400 deg. F., and reaches its maximum at vitrification.

Fire-shrinkage is due to several things; the chemically combined water is driven off (beginning at a dull-red heat); the organic matter contained in the clay is burned out; the size of grains has an influence; also to the amount of volatile substance present in the clay. Some of the clay substance fuses at certain temperatures and flows into and fills the pores of the clay, thus causing shrinkage. On the other hand, quartz has a tendency to counteract fire-shrinkage and in many cases expansion is caused in burning at certain temperatures, but all clays shrink during some stage of burning.

The coarser the sand, the less the shrinkage—this holds true in general as regards the size of grain. Wheeler says*: "The most potent factor in influencing the amount of fire-shrinkage is the size of grain; the finer it is the greater the shrinkage. The amount of lime and magnesia present as carbonate is very important in reducing the shrinkage, which influence is felt when they exceed 2.0 per cent and increases until they exceed 15.0 per cent, when the shrinkage is eliminated. As they are usually present as silicate, which has no noticeable influence in shrinkage, they do not often have to be considered."

THE USE OF GROG.† "Since many clays, when used alone, shrink to such an extent as to cause much loss from warping and cracking, it is necessary to add materials which of themselves have no fire-shrinkage, and so decrease the shrinkage of the mixture in burning. Sand or sandy clays are the materials most commonly used for this purpose, but ground bricks (grog), and even coke or graphite, may be employed. These materials serve not only to decrease the shrinkage in drying and

*Missoure Geol. Survey, Vol. XI, p. 121.
†Clays, by Ries, p. 132.

burning, but also tend to prevent blistering in an easily fusible ferruginous clay when hard-fired. They furthermore add to the porosity of the ware, and thus facilitate the escape of the moisture in drying and in the early stages of burning, as well as enabling the product to withstand sudden changes of temperature. If sand is added for this purpose, it may act as a flux at high temperatures, and this action will be the more intense the finer its grain."

"Large particles of grog are undesirable, especially if they are angular in form, because, in burning, the clay shrinks around them, and the sharp edges, serving as a wedge, open cracks in the clay, which may expand to an injurious degree. Large pebbles will do the same, and at many common brickyards it is not uncommon to see bricks split open during the burning, because of some large quartz-pebbles left in the clay, as the result of improper screening of the tempering sand. For common brick, the type of sand used does not make much difference, as long as it is clean; but if sand is to be added to fire-brick mixtures, it should be coarse, clean, quartz-sand. Burned clay-grog is more desirable than sand for high-grade wares, since it does not affect the fusibility of the clay, or swell with an increase of temperature as sand does, but precaution should be taken to burn the clay to its limit of shrinkage before using it."

DETERMINING THE AMOUNT OF SHRINKAGE.—The method used in measuring the amount of shrinkage of the Kentucky clays reported on was as follows: Each clay was ground to 20-mesh (some to 30-mesh) either by hand or by means of a small laboratory jaw crusher followed by rolls. The samples were thoroughly dried, as nearly all of them had been collected several years before testing, and were easily ground and screened. The clay was kneaded by hand, using a known amount of water, to a uniform dough or paste. The proper consistency and uniformity of the paste was judged by the feel. The paste was molded by hand into briquettes of various sizes, ranging from 1-4 inch to two inches in thickness. The molding was done partly by throwing the clay onto a table and finished by the use of a stiff iron table knife. Many of the clays were used in a small hand press and made into small bricks, 4x2x1-2 to 1 1-4

inches, under a fair pressure. A line was cut, by the sharp point of a pocket knife, exactly one inch in length and short lines cut to indicate the ends of this one-inch line. A steel scale, graduated into hundredths of an inch, was used for all measuring. Some of the test pieces of each clay were dried rapidly in a drying oven while others were allowed to air-dry. When fully dried, the line was carefully measured to the hundredth of an inch and this was noted, also the condition of the dried piece as to cracking or warping. The lines were again measured very carefully after burning to vitrification and thus the air-shrinkage and the fire-shrinkage determined.

By knowing the amount of shrinkage, the manufacturer knows what size his ware must be molded so as to give the proper size when burned. Each clay must be tested for shrinkage under the same conditions of fineness that are used in the plant; the same proportions of water must be used; and the clay burned as in the manufacture of the clay products.

High shrinkage limits the use of a clay, but this damaging quality must be decreased by using grog, as has just been pointed out.

FUSIBILITY.

All clays will fuse, or change from a solid to a liquid condition, if subjected to a sufficiently high temperature. The temperature at which different minerals will fuse will vary greatly, but each will fuse at some definite temperature. The fusion point of a mixture of minerals will vary greatly with the proportions of each present in the mixture, and, because these act upon each other as fluxes, the fusion temperature will be lower than the melting point of some of the mineral in it. Clay is a heterogeneous mixture and does not soften at once in the process of fusing but melts slowly; mineral after mineral fuses until the whole mass softens by a gradual process. It is difficult to determine just what influence one mineral has over another in the process of fusion. It is a common practice in metallurgical operations to add fluxing material in order to lower the fusion point. This is done not only in smelting, assaying, etc., but in preparing alloys for uses that demand a low melting

point. This action may be largely chemical, wholly physical, or a combination of both. In a clay, the most fusible mineral would melt first as the temperature is gradually raised, and this liquid material would act as a solvent and fill the pores of the solid material. Reactions would continue to occur until all the constituents of the clay become fused.

Besides the amount of fluxes, Ries* gives the following things as being what the temperature of fusion depends:

1. The size of grain of the refractory and non-refractory particles.

2. The homogeneity of the mass.

3. The condition of the fire, whether oxidizing or reducing.

4. The form of chemical combination of the elements contained in the clay.

SIZE OF GRAIN.—The fine-grained clays fuse more easily than the coarse-grained ones, of like composition, because of the more intimate contact of the fine grains and partly because each individual grain fuses from the surface inward, and the whole grain is more easily fused if it is small. This allows the fluid to pass into the openings adjacent to it more rapidly and results in causing the whole mass to fuse more quickly.

HOMOGENEITY.*—"Unless the particles of each element or compound are uniformly distributed through the mass they will not produce their maximum effect. Few clays as they occur in nature are perfectly uniform in composition.

"It is sometimes argued from this that in testing clays for their fusibility it is necessary to render them as homogeneous as possible, but in order to obtain results of practical value the clay should not be mixed and ground up any more than it would be for the particular class of clay products to which it is adapted."

CONDITIONS OF FIRE.—If burned in the presence of abundant oxygen the fusion point will be higher than if burned in a reducing atmosphere.

*Clays, by Ries, p. 137.
*Clays, by Ries, p. 144.

STAGES OF VITRIFICATION.—A clay is said to be vitrified when the particles have melted and run together so as to form a glass-like body. This glass-like condition is reached long before the clay becomes a mobile fluid, as the temperature is gradually raised. Wheeler† gives three stages as follows:

INCIPIENT VITRIFICATION.—"On heating a clay beyond red heat it is found to become harder, to shrink, and to become close-grained as the temperature is increased. On heating it still farther, a point is reached when it becomes very hard, attaining a hardness of 6.0 to 6.5 (easily scratching glass); it has almost completed shrinking, it has become very strong, and the individual grains can no longer be recognized. This point is called the point of incipient vitrification. While the clay lacks all signs of fusion and is stiff and rigid at this temperature it shows sufficient flow or movement of the particles toward one another to obliterate individual grains and thereby attains greater density, as it has a decided resemblance to being vitrified."

COMPLETE VITRIFICATION.—"On heating the clay from 100 degrees to 300 degrees F. above this point of incipient vitrification the density is still further increased, by a further and final shrinkage; the hardness becomes somewhat greater, or from 6.5 to 7.0 (now scratching quartz), while the grains are not only completely obliterated, but the fracture is now like that of china or vitrified ware. This point is called the point of complete vitrification and the clay still stiff retains its form and shape, though it shows greater movement among its particles."

VISCOSITY OR SCORIACEOUS VITRIFICATION.—"On heating the clay from 100 degrees to 400 degrees F. still higher the clay begins to warp and sag, slightly at first but more rapidly as the heat is increased, and to swell or blister; while on breaking it is found to be more or less vesicular and scoriaceous. This point is called the point of viscous or scoriaceous vitrification, as the particles are now sufficiently fluid that chemical re-actions begin which give rise to gas bubbles that cause the clay to swell and give it the vesicular structure; and although

†Missouri Geol. Survey, Vol. XI, p. 130, also Clays, by Ries, p. 138.

it is too stiff and pasty to become decidedly liquid, it has attained a temperature when it would fail in all the practical applications of the clay."

"If the temperature is still raised higher, the material becomes more liquid, and finally it is thin enough for the gases set free by the chemical reactions to escape, and it then resembles so much slag. It is now said to be completely fused and on cooling it gives a dense, compact, stony or vitreous fracture; but the clay would have become worthless long before this stage of liquidity is reached, so that the idea of fusibility in this sense has no value to the clay-worker."

PYROMETRIC CONES.

The most common means of measuring fusibility is by means of small conical test pieces which have a given composition, and fuse at approximately known temperatures. These pyrometric cones were first introduced by Hermann A. Seger, a German ceramist, and are often called Seger cones. The composition and fusing points of these cones are given in the following table:*

*Ries. Bull. New York Museum. No. 85, pp. 555-557, also copied by Shedd, in Clays of Washington, pp. 80-83.

No. of cone.	Composition.			Fusing Point. Degrees F.	Fusing Point. Degrees C.
.022	0.5 Na_2O 0.5 PbO		2.0 SiO_2 1.0 B_2O_3	1,094	500
.021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1,148	620
.020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1,202	650
.019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1,256	680
.018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1,310	710
.017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1,364	740
.016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3.1 SiO_2 1.0 B_2O_3	1,418	770
.015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1.0 B_2O_3	1,472	800
.014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1.0 B_2O_3	1,526	830
.013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1.0 B_2O_3	1,580	860
.012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1.0 B_2O_3	1,634	890
.011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1.0 B_2O_3	1,688	920
.010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.50 B_2O_3	1,742	950
.09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.45 B_2O_3	1,778	970
.08	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.60 SiO_2 0.40 B_2O_3	1,814	990
.07	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.65 SiO_2 0.35 B_2O_3	1,850	1,010
.06	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.70 SiO_2 0.30 B_2O_3	1,886	1,030
.05	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.75 SiO_2 0.25 B_2O_3	1,922	1,050
.04	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.80 SiO_2 0.20 B_2O_3	1,950	1,070
.03	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.85 SiO_2 0.15 B_2O_3	1,994	1,090
.02	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.90 SiO_2 0.10 B_2O_3	2,030	1,110
.01	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.95 SiO_2 0.05 B_2O_3	2,066	1,130
1	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	4 SiO_2	2,102	1,150
2	0.3 K_2O 0.7 CaO	0.1 Fe_2O_3 0.4 Al_2O_3	4 SiO_2	2,138	1,170
3	0.3 K_2O 0.7 CaO	0.5 Fe_2O_3 0.45 Al_2O_3	4 SiO_2	2,174	1,190
4	0.3 K_2O 0.7 CaO	0.5 Al_2O_3 —	4 SiO_2	2,210	1,210
5	0.3 K_2O 0.7 CaO	0.5 Al_2O_3 —	5 SiO_2	2,266	1,230

No. of cone.	Composition.	Fusing Point. Degrees F.	Fusing Point. Degrees C.
6	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $0.6\ Al_2O_3 - 6\ SiO_2$	2,282	1,250
7	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $0.7\ Al_2O_3 - 7\ SiO_2$	2,318	1,270
8	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $0.8\ Al_2O_3 - 8\ SiO_2$	2,354	1,290
9	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $0.9\ Al_2O_3 - 9\ SiO_2$	2,390	1,310
10	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $1.0\ Al_2O_3 - 10\ SiO_2$	2,426	1,330
11	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $1.2\ Al_2O_3 - 12\ SiO_2$	2,462	1,350
12	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $1.4\ Al_2O_3 - 14\ SiO_2$	2,498	1,370
13	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $1.6\ Al_2O_3 - 16\ SiO_2$	2,534	1,390
14	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $1.8\ Al_2O_3 - 18\ SiO_2$	2,570	1,410
15	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $2.1\ Al_2O_3 - 21\ SiO_2$	2,606	1,430
16	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $2.4\ Al_2O_3 - 24\ SiO_2$	2,642	1,450
17	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $2.7\ Al_2O_3 - 27\ SiO_2$	2,678	1,470
18	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $3.1\ Al_2O_3 - 31\ SiO_2$	2,714	1,490
19	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $3.5\ Al_2O_3 - 35\ SiO_2$	2,750	1,510
20	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $3.9\ Al_2O_3 - 39\ SiO_2$	2,786	1,530
21	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $4.4\ Al_2O_3 - 44\ SiO_2$	2,822	1,550
22	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $4.9\ Al_2O_3 - 49\ SiO_2$	2,858	1,570
23	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $5.4\ Al_2O_3 - 54\ SiO_2$	2,894	1,590
24	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $6.0\ Al_2O_3 - 60\ SiO_2$	2,930	1,610
25	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $6.6\ Al_2O_3 - 66\ SiO_2$	2,966	1,630
26	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $7.2\ Al_2O_3 - 72\ SiO_2$	3,002	1,650
27	$\left\{\begin{matrix} 0.3\ K_2O \\ 0.7\ CaO \end{matrix}\right\}$ $20\ Al_2O_3 - 200\ SiO_2$	3,038	1,670
28	$Al_2O_3 - 10\ SiO_2$	3,074	1,690
29	$Al_2O_3 - 8\ SiO_2$	3,110	1,710
30	$Al_2O_3 - 6\ SiO_2$	3,146	1,730
31	$Al_2O_3 - 5\ SiO_2$	3,182	1,750
32	$Al_2O_3 - 4\ SiO_2$	3,218	1,770
33	$Al_2O_3 - 3\ SiO_2$	3,254	1,790
34	$Al_2O_3 - 2.5\ SiO_2$	3,290	1,810
35	$Al_2O_3 - 2\ SiO_2$	3,326	1,830
36	$Al_2O_3 - 1.5\ SiO_2$	3,362	1,850

These pyrometric cones are so placed with the clay to be burned that they can be watched from without and their behavior observed. They are not used so much to determine a certain temperature as to indicate when a certain condition of burning has been reached. The following conclusions have been given by Mr. Samuel Geijsbeek.*

First. That Seger or pyrometric cones are very sensitive in their melting, according to a slow or quick fire and that they will melt at a lower temperature in a long duration of firing than in a quick one.

Second. That the Seger or pyrometric cones will melt down at approximately the same temperatures in the same kiln, if used under the same conditions.

Third. That cones which have been used once, and which are therefore biscuited, are of no value for further use, as they give no corresponding results with new cones.

Fourth. That the difference or rate of increase between the melting point of each cone and its succeeding number is not constant and will vary in some cones more than in others.

Fifth. That Seger or pyrometric cones cannot be used to determine exact temperatures, as their melting points are subject to various changes, and therefore any data furnished showing their melting point expressed in degrees of heat is problematical.

Professor Orton† says, "Unfortunate as it is that the use of a printed scale of temperatures was ever started in connection with cones, it is also true that the confusion which would ensue if the idea of temperature were wholly abandoned would be worse than the trouble now existing. Anyone who uses cones regularly for a little while soon learns to use the cones by number, and forgets all about their supposed melting points in the thermometric scale."

Ries‡ gives the following numbers as representing approximately the cones used in the different branches of the clay-working industry in the United States:

*Trans. Am. Cer. So., Vol. XIV, p. 867.

†Ibid. p. 898. Cones may be obtained from Prof. Edward Orton, Columbus, Ohio.

‡Clays, by Ries, p. 153.

Common brick	012-01
Hard burned, common brick	1- 2
Buff front brick	5- 9
Hollow blocks and fire-proofing	03- 1
Terra cotta	02- 7
Conduits	7- 8
White earthenware	8- 9
Fire bricks	5-18
Porcelain	11-13
'Red earthenware	010-05
Stoneware	6- 8

CHAPTER V.

Following are the results of the laboratory tests of the clays of Kentucky, arranged according to counties. Except where otherwise stated, samples were collected by members of the Geological Survey, and analyses made by the survey chemist. Geological positions are given as determined by the collector.

BALLARD COUNTY.

CLAY No. 73.—This sample of gray clay and lignite is from a property in the south part of Wickliffe, Ballard County, Kentucky, owned by the Illinois Central Railroad. The section here is as follows:

1.	Gray clay	7 ft.
2.	Lignite	2 ft.
3.	Gray clay	8 ft.

The geological position is given by the collector as Lignitic of Tertiary.

A sample of this clay gave the following characteristics: Color, gray, both wet and dry; when burned it became a greenish yellow; taste, smooth and exceedingly fat, also free from grit; texture, soft, fine-grained, compact and uniform.

When ground to 30-mesh and mixed with 28.0 per cent of water, it made an exceedingly plastic paste, that stood rapid drying, and that shrank 10.0 per cent in drying and 16.0 per cent more in burning, giving a total shrinkage of 26.0 per cent. The air-dried mud showed a tensile strength of 66 pounds to the square inch, as the average of eight tests, with a maximum strength of 89 pounds.

Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 6 (2,282 degrees F.). It burned to a hard, compact body with considerable warping when in thin slabs.

The high shrinkage and warping of this clay will somewhat limit its usefulness.

CLAY No. 15.—"Bluish plastic clay, from a ravine near the road, three miles east of Blandville, Ballard County. (This is on the Blandville and Lovelace road, and the land is owned by Mr. C. Brown and Mrs. Ellen

Linderman, on the north and south sides of the road respectively. The clay extends under land on both sides. The deposit is covered here by about seven feet of Brown Loam.)"

"On drying, it is of a light-grey color or buff; contains no coarse sand. Before the blow-pipe it fuses with difficulty, and calcines to a light-grey color. It has an observed thickness of about three feet, and underlies a thin bed of red sand. (There is about one foot of gravel above this red sand and recent observations show the clay to be at least seven feet thick.)"*

A sample of this clay gave the following results: Color, very light gray, both wet and dry; burned to cone 1 (2,102 degrees F.), the color is nearly white, taking on a yellowish tint at higher temperatures. Taste, lean and very gritty. Texture, soft, coarse-grained, and compact. When disintegrated by prolonged shaking in water, a small quantity of detritus remained upon the 100-mesh sieve.

Ground to 20-mesh and mixed with 25.0 per cent of water, it made a fairly plastic paste that stood rapid drying, and that shrank 4.0 per cent in drying and 6.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 10.0 per cent. The average tensile strength, as shown by five air-dried test pieces, was 36.5 pounds to the square inch, with a maximum strength of 41.7 pounds.

No vitrification was shown at cone 9 (2,390 degrees F).

This is a refractory clay that would be valuable for the manufacture of stoneware, but it lacks sufficient plasticity and toughness to permit its being turned on a potter's wheel, hence a more plastic clay would be needed to mix with it in order to provide the proper physical properties.

CLAY NO. 39.—Refractory white clay, from one-half mile northwest of Blandville, Ballard county. It is quite plastic, contains no appreciable coarse sand. It is fusible before the blow-pipe, and calcines white.

This property is now (1905) owned by Mrs. Addie Marshall, of Blandville, Ky. The land is adjacent to

*Ky. Geol. Surv. Bull. No. 6, p. 96.

Blandville on the north and the clay exposure is on Fulton Branch. The section here is as follows:

1.	Loam ..	10 ft.
2.	Lafayette Gravel (Stratified Drift)	50 ft.
3.	Stratum of limonite	¼ in.
4.	Grey clay	15 ft. (†)

A sample of this clay, gave the following characteristics: Color, yellowish gray to gray; mixed, the color is gray; burned to cone 1 (2,102 degrees F.), the color is pale yellow with reddish tints, becoming a pale cream at higher temperatures. Taste, very fat, with some fine grit. Texture, soft, fine-grained, rather compact. When disintegrated by prolonged shaking in water, no detritus remained upon the 100-mesh sieve: very easily disintegrated. None of the limonite was used in the mixture tested.

When ground to 20-mesh and mixed with 24.0 per cent of water, it made a very plastic paste that stood rapid drying, and that shrank 3.0 per cent in drying and 2.0 per cent additional in burning to cone 7 (2,318 deg. F.), giving a total shrinkage of 5.0 per cent. The tensile strength of the air-dried mud, as shown by the average of six tests, was 63.7 pounds to the square inch, with a maximum strength of 72 pounds. Incipient vitrification occurred at cone 6 (2.282 deg. F.), and nearly complete at cone 11 (2,462 deg. F.). It burned to a hard, compact body free from warping.

This is a high-grade, semi-refractory clay and should have much commercial value.

CLAY No. 13. River Lot No. 4, in the northeast part of Wickliffe, Ballard county. Here there is a deposit of gray, plastic clay giving the following section:

1.	Loam and Loess	10-30 ft.
2.	Gravel (Lafayette)	3-10 ft.
3.	Grey, plastic clay	20 ft.

This clay property is owned by a company composed of Dr. N. L. Rogers, Dr. J. C. Boone, Mr. Augustus Keppner, and Mr. J. H. Thorp.*

†Ibid. p. 93.
*Ky. Geol. Surv. Bull. No. 6, p. 94.

A sample of this clay gave the following: Color, gray with yellow portions, when ground the color was yellow, both wet and dry; when burned to cone 1 (2,102 deg. F.) the color was reddish-yellow, becoming cream at cone 6 (2,282 deg. F.) and pale yellow at higher temperatures. Taste, lean and very gritty. Texture, sandy, massive and coarse-grained. When disintegrated by prolonged shaking in water, practically no detritus was left on the 100-mesh sieve.

When ground to 20-mesh and mixed with 22.0 per cent of water, it made a fairly plastic to lean paste that shrank 7.0 per cent in drying and 3.00 per cent additional in burning, giving a total shrinkage of 10.0 per cent. Briquettes of the air-dried mud have an average tensile strength of 115.6 pounds to the square inch with a maximum of 145.1 pounds. This average was obtained by six tests.

At cone 9 (2,390 deg. F.) there was very little indication of vitrification.

This clay is used at the Wickliffe Pottery.

CLAY No. 6. This clay occurs about one mile northeast of Blandville, Ballard county. The bed is ten feet thick and lies beneath 42 feet of gravel and loam. Geological position, Wilcox Formation, Eocene Series, Tertiary System.

A sample of this clay gave the following characteristics: Color, nearly white when dry, becoming gray when wet; when burned to cone 1 (2,102 degrees F.), the color was nearly white, but turned to cream at higher temperatures and remained so at cone 9 (2,390 degrees F.). Texture, soft, and fine-grained leaving no detritus on the 100-mesh sieve after disintegration by prolonged shaking in water.

When ground to 20-mesh and mixed with 26.0 per cent of water, it made a very plastic paste that shrank 7.0 per cent in drying and 5.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 12.0 per cent. It stands rapid drying but warps somewhat in burning. The tensile strength, as shown by the average of fourteen tests,was 112 pounds to the square inch, the maximum being 130 pounds. Incipient vitrification occurred at cone 7 (2,318 degrees F.), and nearly complete at cone 9 (2,390 degrees F.).

This is a good clay and will make beautiful face brick.

CLAY No. 3. Yellow ochre, from the Harkless place, immediately north of Wickliffe, Ballard county. On calcining, it became a handsome Venetian red color, and fuses before the blow-pipe into a blackish mass. (Found also on John Rothrock's place. Thickness, six feet.)

Composition of the Ochreous Clays of Ballard County.

Silica	44.840
Alumina	22.831
Iron peroxide	20.350
Lime	0.101
Magnesia	0.138
Water, etc.	11.740
Total	100.000(*)

The bed is from seven to twelve feet thick and underlaid by two and one-half feet of lignite, with dark drab clay below the lignite. (The drab clay is clay No. 2 in this volume.) Geological position, Base of Lafayette.

A sample of this clay gave the following characteristics: Color, yellow both wet and dry; when burned to cone 1 (2,102 degrees F.), the color was light red, becoming dark red up to cone 7 (2,354 degrees F.), and then a gun metal blue at cone 9 (2,390 degrees F.). Taste, lean and very gritty. Texture, sandy and coarse-grained containing a considerable quantity of rock-like particles which were exceedingly difficult to disintegrate by prolonged shaking in water.

When ground to 20-mesh and mixed with 23.0 per cent of water, it made a slightly plastic paste, that shrank 2.5 per cent in drying and none in burning, giving a total shrinkage of 2.5 per cent. Incipient vitrification occurred at cone 9 (2,390 degrees F.). It stood rapid drying. The tensile strength, as shown by the average of four tests, was 70 pounds to the square inch, with a maximum strength of 80 pounds.

This is a good clay for such purposes as the manufacture of drain tile.

*Ky. Geol. Surv., Bull. No. 6, p. 114.

CLAY NO. 2. This clay represents the dark drab clay under the lignite mentioned in connection with Clay No. 3.

The sample of this clay gave the following characteristics: Color, light drab when dry and darker drab when wet; when burned to cone 1 (2,102 degrees F.), the color was pale yellow, becoming a grayish-yellow at higher temperatures. Texture, soft, fine-grained; when disintegrated by prolonged shaking in water, much lignite particles were caught on the 100-mesh sieve, but no grit. Taste, fat, almost free from grit.

When ground to 20-mesh and mixed with 32.0 per cent of water, it made a very plastic paste that shrank 7.0 per cent in drying and a like amount in burning, giving a total shrinkage of 14.0 per cent. It stood rapid drying. The tensile strength, as shown by two tests, was 112.8 pounds to the square inch, both tests giving the same result. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 8 (2,354 degrees F.).

This is a fair quality of pale yellow burning clay.

CLAY NO. 4. A mixture of equal weights of Clay No. 2 and Clay No. 3 gave the following results: Color, yellowish brown when dry and dark yellow when wet; when burned to cone 1 (2,102 degrees F.), the color was yellowish red, becoming a yellowish-tinted brown with black spots at cone 9 (2,390 degrees F.).

When ground to 20-mesh and mixed with 24.0 per cent of water, it made a fat paste, that shrank 6.0 per cent in drying and 4.0 per cent more in burning, giving a total shrinkage of 10.0 per cent. It stood rapid drying. Tensile strength (one test only) was 122.3 pounds to the square inch. Vitrification nearly complete at cone 9 (2,390 degrees F.).

CLAY NO. 1. The William Henderson Place, one mile northeast of Wickliffe, near the Wickliffe and Barlow road. Here there is a deposit of clay showing the following exposure:

1.	Gravel (Lafayette)	3 ft. (Hill, 30 ft.)
2.	Ochreous clay	2 ft.
3.	Lignitic clay	10 in.
4.	Grey, plastic clay	7 ft.

This exposure is at the base of a hill about thirty feet high and appears to be quite extensive horizontally as well as vertically. The deposit continues on the property of Mr. B. F. Billington on the west.*

The sample of this clay gave the following characteristics: Color, very light gray, both wet and dry; when burned, the clay was white at all temperatures. Taste, slightly fat and gritty. Texture, soft and fine-grained; when disintegrated by prolonged shaking in water, very little detritus remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 29.0 per cent of water, it made a rather fat paste that shrank 5.0 per cent in drying and alike amount in burning, giving a total shrinkage of 10.0 per cent. The tensile strength, as the average of five tests, was 52.6 pounds to the square inch with a maximum strength of 55 pounds. Incipient vitrification occurred at cone 11 (2,462 degrees F.). This is an excellent white-burning clay.

CLAY No. 5. Clay from Mr. Samuel's farm, four miles south of Blandville, Ballard county. (This farm is on the Bardwell and "Rose Cross-Roads" road, and is at present (1905) owned by Mr. W. Z. T. Smith.

A section of the deposit follows:

1.	Soil	1 ft.
2.	Loam	2½-5 ft.
3.	Gravel	2 ft.
4.	Iron layer (limonite)	1 in.
5.	Grey, plastic clay	4+ft.

This clay exhibits minute spangles of mica under the lens; heated before the blow-pipe, it becomes first dark colored, then burns white. (There is about one hundred and sixty acres of land underlaid by the deposit as shown by outcrops.)* Geological position, Base of Lafayette.

A sample of this gray, plastic clay gave the following characteristics: Color, brownish gray when dry, dark gray to brown when wet; when burned to cone 1 (2,102 degrees F.), the color was grayish white and re-

*Ky. Geol. Surv., Bull. No. 6, p. 94.
*Ky. Geol. Surv., Bull. No. 6, p. 95.

mained so at all higher temperatures. Taste, fairly fat with some grit. When disintegrated by prolonged shaking in water, a small quantity of clear, sharp quartz grains were caught on the 100-mesh sieve.

When ground to 20-mesh and mixed with 23.0 per cent of water, it made a fairly plastic paste, that stood rapid drying, and shrank 5.0 per cent in drying and 2.0 per cent more in burning, giving a total shrinkage of 7.0 per cent. The tensile strength, as shown by the average of eight tests, was 76.9 pounds to the square inch, with a maximum strength of 89.4 pounds. Incipient vitrification occurred at cone 7 (2,318 degrees F.), and nearly complete at cone 9 (2,390 degrees F.). This is a good grade of nearly white-burning clay.

The analysis of this clay, made for the Survey by the Kentucky Agricultural Experiment Station, is as follows:

Chemist's No. 2666.

	Per cent.
Moisture	1.78
Ignition (combined water and volatile matter)	9.37
Silica	60.44
Alumina	22.69
Ferric oxide	1.65
Lime	0.34
Magnesia	0.06
Potash	0.91
Soda	0.22
Titanium dioxide	1.40
Sulphur trioxide	tr.
Total	98.86

BATH COUNTY.

CLAY No. 159. (Chemist's No. 3,302). Flint clay sent by Mr. F. J. Pischel, of Salt Lick, Bath County, Kentucky.

The sample consisted of a rather large sized hand specimen of dark gray flint clay, very hard and compact, apparently free from grit, breaks with a conchoidal fracture, some ferruginous coating on the weathered face.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.02
Combined water, etc.	13.78
Silica	42.76
Alumina	39.60
Ferric oxide	0.96
Calcium oxide	0.12
Magnesium oxide	tr.
Potassium oxide	0.57
Sodium oxide	0.13
Titanium dicxide	0.80
Sulphur trioxide	tr.
Total	99.47

The analysis shows that this is a good quality of flint clay. It should be quite refractory in the fire.

The sample of this clay gave the following characteristics: Color, dark gray; burned to a creamy white. Taste, lean and very gritty. When ground to 20-mesh and mixed with 21.0 per cent of water, it made a paste very low in plasticity, that shrank almost none in drying and 10.0 per cent in burning to cone 9 (2,390 degrees F.). The air-dried mud showed an exceedingly low tensile strength. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 11 (2,462 degrees F.). This is a semi-refractory clay of fair quality.

BREATHITT COUNTY.

CLAY No 154. Fire clay from Shack Branch, about one mile above Guage, on the right side of Quicksand creek, Breathitt county. This clay is over the Dean coal.

A sample of this clay gave the following characteristics: Color, pinkish yellow; burned to a greenish yellow. Taste, very hard and gritty. When ground to 20-mesh and mixed with 24.0 per cent of water, it made an exceedingly lean paste, that shrank none in drying and 5.0 per cent in burning to cone 11 (2,462 degrees F.). It dried to a crumbly body, almost wholly wanting in tensile strength. Vitrification was practically complete at cone 11 (2,462 degrees F.). It burned to a rather porous body.

This is a semi-refractory clay that will make a pretty buff-colored pressed brick.

BRECKINRIDGE COUNTY.

CLAY No. 86. (Chemist's No. 3,130.) Clay from 40-foot bed, Chester marl at Stephensport, Breckinridge county.

Sample consisted of several pounds of red shaley material containing considerable iron oxide and small amounts of carbonate.

Analysis of Air-Dried Sample.

	Per cent.
Moisture	4.03
Combined water	2.70
CO_2	5.93
SiO_2	49.30
Al_2O_3	19.36
Fe_2O_3	7.60
FeO	0.70
CaO	2.18
MgO	2.17
K_2O	4.93
Na_2O	0.04
TiO_2	0.40
SO_3	none
P_2O_5	none
Total	99.36

Should make vitrified brick.

A sample of this clay, gave the following characteristics: Color, brown; burned dark red at cone 1 (2,102 degrees F.), and very dark red at higher temperatures. Taste, lean and rather free from grit. When ground to 20-mesh and mixed with 18.0 per cent of water, it made a lean paste, that stood a fair rate of drying and that shrank 5.0 per cent in drying and a like amount in vitrifying, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 69 pounds to the square inch, with a maximum strength of 94.7 pounds. Complete vitrification occurred at cone 2 (2,138 degrees F.). This is a drain tile and common brick clay.

CLAY No. 85. (Chemist's No. 3,131.) Chester marl from Buffalo Wallow, Breckinridge county. Bed about twenty feet thick. The sample consisted of dark gray marl. Contained carbonates, and fusible in the blowpipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Combined water	5.86
Moisture	3.04
CO_2	1.51
SiO_2	58.00
Al_2O_3	15.06
Fe_2O_3	7.36
FeO	0.50
CaO	2.36
MgO	2.69
K_2O	3.28
Na_2O	0.64
TiO_2	0.50
SO_3	tr.
P_2O_5	none
Total	100.80

Ratio of Iron and Alumina to Silica, 2.53. This should answer as a material for making Portland Cement, though the potash is a little high and the ratio at the low limit.

A sample of this clay, gave the following characteristics: Color, green; burned to dark red at cone 1 (2,102 degrees F.), and to a dark brown at higher temperatures. Taste, lean and somewhat gritty. When ground to 20-mesh and mixed with 20 per cent of water, it made a lean paste that required slow drying and that shrank 7.5 per cent in drying and 10.0 per cent more in vitrifying, giving a total shrinkage of 17.5 per cent. The air-dried mud showed a tensile strength of 120 pounds to the square inch, as the average of ten tests, with a maximum strength of 141 pounds. Incipient vitrification occured below cone 1 (2,102 degrees F.), complete at cone 4 (2,210 degrees F.), and partially viscous at cone 6 (2,282 degrees F.). This clay will do for the manufacture of common brick and tile.

CALLOWAY COUNTY.

CLAY NO. 113. Yellow clay one-half mile south of Murray, Calloway county. Overlaid by ten feet of Lafayette gravel which has a thickness of twenty-five feet. This gravel is used for ballast. About ten feet of the clay is exposed at the south cut. Property owned by the N. C. & St. L. R. R. Sample consisted of rather large sized lumps of yellow clay somewhat banded by white clay. Fusible in blow-pipe flame.

Analysis of An Air-dried Sample:

	Per cent.
Moisture at 100° C.	3.33
Combined water	8.08
Silica	60.72
Alumina	14.06
Ferric oxide	11.07
Ferrous Oxide	0.29
Calcium oxide	0.14
Magnesium oxide	1.08
Titanium dioxide	0.40
Potassium oxide	1.50
Sodium oxide	0.06
Total	100.73
Ratio of Silica to Iron and Alumina	2.39

The chemist remarked as follows: "The analysis shows that this clay could probably be used in making brick or terra cotta."

A sample of this clay gave the following characteristics: Color, bright yellow; burned dark red. Taste, very fat and free from grit. Texture, soft, fine-grained. When ground to 20-mesh and mixed with a great quantity of water, 75.0 per cent, it made a very plastic paste, that stood rapid drying, and that shrank 8.0 per cent in drying and 19.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 27.0 per cent. The air-dried mud showed a tensile strength of 69 pounds to the square inch. Incipient vitrification occurred at cone 7 (2,318 degrees F.), complete at cone 11 (2,462 degrees F.). The clay burned to a good body but warped considerably. This is a semi-refractory clay.

It has a yellow color that should be well suited to the manufacture of mineral paint.

CLAY No. 97. (Chemist's No. 3139.) A. B. Edwards clay, near Mayfield and Murray Road, about eight miles northwest of Murray, Calloway county. Geological position, Base of Tertiary. Thickness, five feet exposed. The analysis of this clay is as follows:

Air-dried Sample:

	Per cent.
Moisture at 100° C.	0.62
Combined water	6.54
Silica	67.80
Alumina	20.10
Ferric oxide	1.50
Ferrous oxide	0.43
Calcium oxide	tr.
Magnesium oxide	0.54
Titanium dioxide	0.50
Potassium oxide	1.54
Sodium oxide	0.53
Sulphur trioxide	none
Phosphoric acid	none
Total	100.13
Ratio of Silica to Alumina and Iron	3.05

The chemist remarked as follows: "The analysis shows that the material is just right for a Portland Cement clay. It should be a good siliceous fire clay or potters' clay."

A sample of this clay gave the following characteristics: Color, almost white; burned white, changing to gray at cone 9 (2,390 degrees F.). Taste, fat and rather free from grit. Texture, soft and fine-grained. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a plastic paste that shrank 5.0 per cent in drying, and an additional 10.0 per cent when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 21 pounds to the square inch. It burned to a hard, compact body when vitrified, which was at cone 9 (2,390 degrees F.). Incipient vitrification occurred at cone 5 (2,246 degrees F.). This is an excellent grade of very light-burning clay, and should make a good grade of pressed brick of a desirable color.

CLAY No. 116. (Chemist's No. 3140). Clay from Base of Lafayette on the W. K. Russell place, and used for the manufacture of jugs, jars, etc., at Russell's Pottery. The deposit is located at Potterstown, about six miles east of Murray, Calloway County, and is from four to ten feet thick. An analysis of this clay is as follows:

Analysis of air-dried Sample.

	Per Cent.
Moisture at 100° C.	1.30
Combined water	10.00
Silica	57.24
Alumina	27.74
Ferric oxide	1.28
Ferrous oxide	0.14
Calcium oxide	1.04
Magnesium oxide	0.25
Potassium oxide	0.71
Sodium oxide	0.13
Titanium dioxide	1.00
Sulphur trioxide	none
Phosphoric acid	none
Total	100.83

The chemist remarked as follows: "The analysis shows that this clay should be a very good, white refractory clay."

A sample of this clay gave the following characteristics: Color, pink; burned to a beautiful pink, changing above cone 6 (2,282 degrees F.) to a slightly yellowish white. Taste, fat, smooth, free from grit. Texture, soft, fine-grained, uniform. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a plastic paste that stood rapid drying and that shrank 8.0 per cent in drying and 6.0 per cent additional when vitrified, giving a total shrinkage of 14.0 per cent. The air-dried mud showed a tensile strength of 65 pounds to the square inch. It burned to a hard, compact body. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 9 (2,390 degrees F.). This should make a very high-grade pressed brick and terra cotta clay.

CLAY No. 106. (Chemist's No. 3138.) This place is near the Mayfield and Murray Road, eight miles north-

west of Murray, Calloway county. Here two feet of black pyriticous clay is exposed at the Base of the Quaternary.

A sample of this clay gave the following characteristics: Color, gray; burned pink, and then to a gray at higher temperatures. Taste, all grit. Texture, sandy. When ground to 20-mesh and mixed with 30.0 per cent of water, it made an exceedingly lean paste—almost void of plasticity—that shrank 2.5 per cent in drying and none in burning, gaving a total shrinkage of 2.5 per cent. The air-dried mud had a tensile strength of only eight pounds to the square inch. There was no indication of vitrification at cone 11 (2,462 degrees F.). This is a fair grade of fire clay.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	0.87
Combined water	4.35
Silica	76.68
Alumina	12.31
Ferric oxide	1.12
Ferrous oxide	1.01
Calcium oxide	0.28
Magnesium oxide	0.74
Potassium oxide	1.71
Sodium oxide	0.29
Titanium dioxide	0.25
Sulphur trioxide	tr.
Phosphoric acid	none
Total	99.62

The analysis shows that the material is quite siliceous and should be quite refractory.

CARLISLE COUNTY.

CLAY No. 68. The Marion Hogancamp place. Mr. Hogancamp lives on the Columbus and Cairo Road, one mile northeast of Laketon, Carlisle county. Here is exposed six feet of gray ochreous clay at the top of the LaGrange of the tertiary.*

*Ky. Geol. Surv., Bull. No. 6, p. 114.

A sample of this clay gave the following characteristics: Color, yellowish, pink and green; yellow when ground and mixed and pinkish yellow when burned. Taste, fat and gritty. Texture, soft, coarse-grained, compact. When ground to 30-mesh and mixed with 25.0 per cent of water, it made a fat paste that stood rapid drying and that shrank 7.0 per cent in drying and an additional 9.0 per cent when vitrified, giving a total shrinkage of 16.0 per cent. The air-dried mud showed a tensile strength of 134 pounds to the square inch, as the average of only two tests. Incipient vitrification occurred at cone 7 (2,318 degrees F.), complete at cone 11 (2,462 degrees F.). It burned to a hard, compact body of a beautiful pinkish yellow color.

CLAY No. 12. Plastic clay, from George Ryan's place on the north bluff of Little Mayfield Creek, four miles northeast of Milburn, Carlisle county. This property is now (1905) owned by Mrs. E. J. Carrico. The exposure is along the Bardwell and Kirbytown Road, seven miles east of Bardwell. It is exposed in a number of places along the bluff with a thickness of four feet. It is very stiff, and contains some fine sand. It is infusible before the blow-pipe and calcines to a light gray color.* Geological position, Base of Lafayette.

A sample of this clay gave the following characteristics: Color, gray with yellow spots; ground and mixed it was gray when dry, becoming darker when wet; burned to cone 1 (2,102 degrees F.), the color was a pale yellow, turning to a muddy gray with a yellowish tint above cone 6 (2,282 F.). Taste, fat and gritty. Texture, sandy, uniform. When disintegrated by prolonged shaking in water. no detritus remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 33.0 per cent of water, it made a plastic paste, that stood rapid drying and that shrank 8.3 per cent in drying and 4.6 per cent of water, it made a plastic paste, that stood rapid per cent. The tensile strength of the air-dried mud, as shown by the average of six tests, was 164.5 pounds to the square inch, with a maximum strength of 216.6 pounds. Incipient vitrification occurred at cone 2 (2,138

*Ky. Geol. Surv., Bull. No. 6, p. 95.

degrees F.), complete at cone 5 (2,246 degrees F.). It burned to a compact, strong body when vitrified. It should make a good stoneware clay.

CLAY No. 11. This clay is from the farm of Dr. T. S. Terrell, two and one-half miles north of Laketon, Kentucky.

A sample of the upper four feet of this clay gave the following characteristics: Color, when dry, gray with slight yellowish tint, dark gray when wet; when burned to cone 1 (2,102 degrees F.), it was a pretty, bright yellow, but turned to a muddy gray at higher temperatures. Texture, soft, fine-grained, and, when disintegrated by prolonged shaking in water, practically all passed through the 100-mesh sieve. Taste, fat and free from grit.

When ground to 20-mesh and mixed with 22.0 per cent of water, it made a plastic paste that shrank 9.0 per cent in drying and 5.0 per cent more in burning, giving a total shrinkage of 14.0 per cent. The tensile strength of the air-dried mud, as shown by the average of 16 tests, was 197.5 pounds to the square inch, with a maximum strength of 252.7 pounds. Incipient vitrification occurred at cone 6 (2282° F.), complete at cone 9 (2390° F.) At cone 9, small particles of the clay had fused and run out.

This clay will give beautiful color for brick or tile at the lower temperatures, below 2138° F.

CLAY No. 7. The Wm. Reynolds Place. This is near the Columbus and Cairo Road, three miles north of Berkley, Carlisle county. Here there is a very pretty pink and yellowish clay at the Base of the Lafayette gravel, showing the following section:

1.	Loess	10 ft.
2.	Pebbles and conglomerate iron	1 ft.
3.	Pink and yellow clay	8 ft.

This exposure is along a branch or drain at the foot of high bluffs of loess and may be traced around on the property of Mr. B. F. Gannaway on the south and Mr. M. R. Holland on the east.*

* Ky. Geol. Surv., Bull. No. 6, p. 97.

A sample of this clay gave the following characteristics: Color, pink, both wet and dry (sample, unmixed, was pink with yellow streaks); the color remained pink up to cone 6 (2,282 degrees F.), but became a pale yellow, approaching white, at higher temperatures. Taste, fat and gritty. Texture, soft and coarse-grained. When disintegrated by prolonged shaking in water, practically all detritus passed through the 100-mesh sieve. Ground to 20-mesh and mixed with 28.0 per cent of water, it made a fat paste, that stood rapid drying, and that shrank 9.0 per cent in drying and 5.0 per cent additional in burning, giving a total shrinkage of 14.0 per cent. The tensile strength of the air-dried mud, as shown by the average of eight tests, was 112.6 pounds to the square inch, with a maximum strength of 126.3 pounds. Incipient vitrification occurred at cone 9 (2,390 degrees F.). This is a high grade, nearly white-burning clay.

CLARK COUNTY.

CLAY No. 146. This clay is from the same farm as Clay No. 67. (See A. H. Anderson's place, Powell county.)

A sample of this clay gave the following characteristics: Color, green; burned to a dark red. Taste, lean to fat, smooth. When ground to 20-mesh and mixed with 23.0 per cent of water, it made a fairly plastic paste, that shrank 7.5 per cent in drying and an additional 5.0 per cent when vitrified, giving a total shrinkage of 12.5 per cent. The air-dried mud showed a tensile strength of 74 pounds to the square inch, as the average of six tests, with a maximum strength of 80 pounds. Complete vitrification occurred at cone 1 (2,102 degrees F.). It burned to a fair body and should make excellent common brick and drain tile.

CLAY No. 122. The Morgan Eubank place. Mr. Eubank's farm is on the Indian Fields and Irvine Road, four miles south of Indian Fields, Clark county.

On this place, and the one adjacent on the west, belonging to Mr. D. J. Snowdon, there is quite an extensive deposit of greenish, plastic clay. By hand-level measurements of the deposit as exposed along large gullies,

the thickness averages about twenty-one and a half feet. It is found at various points of exposure over an area of perhaps one hundred acres. This is a Niagaran deposit, and it is quite likely that back some distance into the hills, as would be reached by tunneling, the material would become shaley in character.

Following is a section of the deposit as exposed along the gullies:

1.	Dark, brown limestone	4 ft.
2.	Greenish, plastic clay	5½ ft.
3.	More compact laminated clay	6 ft.
4.	Drab clay, very fat	10 ft.

This deposit belongs, doubtless, to what Prof. Foerste calls the Estill Clay of the Crab Orchard Division of the Silurian Series.*

A sample of this clay gave the following characteristics: Color, green; burned dark red, and dark brown when fused. Taste, fat, almost free from grit. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying and a like amount in burning to vitrification, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 105 pounds to the square inch. Complete vitrification occurred at cone 02 (2,030 degrees F.), and viscosity at cone 6 (2,282 degrees F.).

CLAY No. 66. The Orlando Hensley place. Mr. Hensley lives on the Indian Fields and Pine Ridge Road, about two and a half miles east of Indian Fields, Clark county. About one-half mile north of Mr. Hensley's home, on a small spring branch which flows into Lulbegrud Creek, there is an exposure of yellow, ochreous clay about four feet thick. The exposure runs fifteen or twenty yards along the branch to its head, which is a chalybeate spring issuing from above the ochreous clay deposit. The clay is covered above by vegetation and hidden by the branch below, but it is evidently Devonian and has resulted from residues from the Ohio Black Shale.

Following is the analysis of the clay, made for the Survey by the State Agricultural Experiment Station:

*Ky. Geol. Survey, Bull. No. 6, p. 65.

	Per cent.
Hygroscopic moisture	3.04
Combined water and volatile matter	12.28
Silica	44.40
Alumina	11.35
Ferric oxide	24.69
Lime	0.26
Magnesia	0.38
Potash	1.99
Soda	0.26
Titanium dioxide	0.75
Sulphur trioxide	0.56
Phosphorous pentoxide	0.13
Total	100.09

Higher up the hills and across a hollow to the north from the above described deposit about one-half a mile, there is a deposit of pinkish, plastic clay about six feet deep. The deposit is at the top of the Devonian or Ohio Black Shale.

The following is a section made at this deposit:

1.	Soil	2 ft.
2.	Pinkish clay	6 ft.
3.	Black shale	Flat exposure.(*)

A sample of this "pinkish-red clay" gave the following characteristics: Color, when mixed, pale pinkish red; dark red when burned. Taste, fat and very little grit. Texture, soft, fine-grained. When ground to 30-mesh and mixed with 24.0 per cent of water, it made a fat paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 7.0 per cent additional when vitrified, giving a total shrinkage of 12.0 per cent. The air-dried mud showed a tensile strength of 58 pounds to the square inch, as the average of three tests, with a maximum strength of 67.3 pounds. The clay burned to a hard, compact body, free from warping. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 7 (2,318 degrees F.).

CLAY No. 65. The B. L. Bruner place. The clay on this farm is exposed along the Indian Fields and Clay

Ky. Geol. Surv., Bull. No. 6, p. 67, analysis also on p. 194.

City Road about two miles from Indian Fields, Clark county. The clay is exposed on both sides of the named road and outcrops on several hillsides around in the immediate vicinity.

It is a greenish, plastic clay resulting from Crab Orchard Shale and shows an average thickness of about four and one-half feet. A very luxuriant plant growth on the thin soil above the clay testifies to plant food contained therein. These Crab Orchard clays, as a rule, contain a noteworthy amount of potash.

The following is a section of this clay as exposed by gullies, eroded hillsides, etc.:

Soil	2 ft.
Greenish, plastic clay	4½ ft. (†)

A sample of this clay gave the following characteristics: Color, green; burned to very dark red. Taste, fat, very little grit. Texture, soft, fine-grained, massive. When ground to 30-mesh and mixed with 28.0 per cent of water, it made a very plastic paste, that required slow drying and that shrank 7.0 per cent in drying. The air-dried mud showed a tensile strength of 138 pounds to the square inch, as the average of three tests, with a maximum strength of 151 pounds. The clay was partially fused to viscosity at cone 6 (2,282 degrees F.). Complete vitrification occurred much below this temperature. This is a low-grade clay suited only to the manufacture of common brick and tile.

CLAY NO. 46. The Robert Kidd place. This land is on the Indian Fields and Mt. Sterling Road, three miles north of Indian Fields, Clark county. Here the hills over an area of about one hundred and twenty-five acres, show exposures of a greenish, plastic clay about ten feet thick as an average. The clay is Crab Orchard in age and occurs immediately below a three-foot stratum of Corniferous Limestone. The clay is a very fat material, free from gravel, sandy grit, etc.

The following is an average section of the exposures around the hillsides:

†Ibid., p. 68.

1.	Devonian (Corniferous) Limestone	3 ft.
2.	Greenish clay (Silurian)	10 ft.

This clay is very similar in appearance to other Crab Orchard clays which have been recommended for Portland Cement.*

A sample of this clay gave the following characteristics: Color, green, both wet and dry; when burned, the color was pale yellow. Taste, lean and gritty. Texture, soft and fine-grained, massive and uniform. When ground to 30-mesh and mixed with 24.0 per cent of water, it made a mildly plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 4.0 per cent more when vitrified, giving a total shrinkage of 9.0 per cent. The air-dried mud showed a tensile strength of 88.3 pounds to the square inch, as the average of eleven tests, with a maximum strength of 106.4 pounds. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 9 (2,390 degrees F.). Thin pieces showed no warping. This clay should make terra cotta.

CLAY No. 40. The Kiddville Exposures. There is a small wet-weather branch which flows through the west side of Kiddville, crosses the Indian Fields and Kiddville Road and empties into Lulbegrud Creek one mile southeast of Kiddville, Clark county, Ky. Along this branch, west of the town, there are exposures of a greenish Crab Orchard clay on Messrs. A. T. and J. H. Pieratt. On Mr. A. T. Pieratt the exposure by lock level measurement shows to be about twenty-one and a half feet thick on both sides of the branch. Similar exposures are found to the south on Mr. J. H. Pieratt and Dr. J. F. Lockhart; to the west on Mr. J. Eubank and Mr. James Peel; to the north on Mrs. Carrie Hardy; to the east, Mr. J. L. Jackson and Mrs. Mary Elliott. The following is the section as exposed:

1.	Soil with grass	2 ft.
2.	Greenish, plastic clay	15 ft.
3.	Deeper green clay	5½ ft.
4.	Covered. (†)	

*Ky. Geol. Surv., Bull. No. 6, p. 68.
†Ky. Geol. Surv., Bull. No. 6, p. 69.

A sample of this clay from the J. H. Pieratt place gave the following characteristics: Color, green, both wet and dry; it burned to a dark brown. Taste, fat, with very little grit. Texture, soft, fine-grained, somewhat shaley. When disintegrated by prolonged shaking in water, considerable jet-black sand was caught on the 100-mesh sieve.

When ground to 20-mesh and mixed with 30.0 per cent water, it made a plastic paste, that shrank 8.0 per cent in drying. The air-dried mud showed a tensile strength, as the average of eight tests, of 119.5 pounds to the square inch, with a maximum strength of 141.4 pounds. Fusion occurred at cone 6 (2,282 degrees F.). This is a very low-grade clay.

CLAY No. 53. A. T. Pieratt place. A sample of this clay gave the following characteristics: Color, green; it burned to dark brown. Taste, fat, very little grit. Texture, soft, fine-grained and full of roots and fibers. When ground to 30-mesh and mixed with 28.0 per cent of water, it made a plastic paste that stood rapid drying, and that shrank 5.0 per cent in drying and 1.0 per cent more in burning, giving a total shrinkage of 6.0 per cent. The air-dried mud showed a tensile strength of 127.5 pounds to the square inch, as the average of six tests, with a maximum strength of 158 pounds. The clay was fully vitrified at cone 4 (2,210 degrees F.), and partially fused at cone 7 (2,318 degrees F.). This is a low-grade clay of very doubtful commercial value.

CLAY No. 118. Crab Orchard Clay, from big clay pit, one mile west of Indian Fields, Clark county, Ky. Collected by Aug. F. Foerste, "B 14."

Small sample of yellow shaley clay, not an average sample. Fusible in the blow-pipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.02
Combined water and organic matter	5.41
Silica	58.48
Alumina	19.33
Ferric oxide	6.08
Ferrous oxide	1.01

	Per cent.
Calcium oxide	0.82
Magnesium oxide	2.27
Potassium oxide	4.58
Sodium oxide	0.89
Titanium dioxide	0.45
Sulphur trioxide	tr.
Phosphoric acid	tr.
Total	100.34
Ratio of Iron and Alumina to Silica	2.20

The analysis shows that this clay is not quite siliceous enough for making Portland Cement.

The sample of this clay gave the following characteristics: Color, green, with yellow tint; burned to a very dark red. Taste, fat and very little grit. When ground to 20-mesh and mixed with 26.0 per cent of water, it made a fat paste, that shrank 7.0 per cent in drying and a like amount when vitrified, giving a total shrinkage of 14.0 per cent. Complete vitrification occurred at cone 03 (1,994 degrees F.), partial viscosity at cone 5 (2,246 degrees F.). This is a common-brick clay only.

CLAY NO. 84. W. T. Stanhope place. This place is near the Indian Fields and Irvine Road, about two miles south of Indian Fields, Clark county, Ky.

The analysis of an air-dried sample of this clay, by J. S. McHargue, Survey Chemist, is as follows:

Average Sample of Yellow Clay Containing Gravels and a Few Roots:

	Per cent.
Moisture at 100° C.	1.94
Combined water and organic matter	5.79
Silica	63.28
Alumina	17.95
Ferric oxide	4.48
Ferrous oxide	1.01
Calcium oxide	tr.
Magnesium oxide	1.19
Potassium oxide	4.29
Sodium oxide	0.29
Titanium dioxide	0.45
Sulphur trioxide	tr.
Phosphoric acid	none
Total	100.67
Ratio of Iron and Alumina to Silica	2.68

The chemist remarked as follows: The analysis shows that this clay would answer for a Portland Cement clay, though the potash is rather high."

A sample of this clay gave the following characteristics: Color, yellow; burned to a yellowish red at cone 1 (2,102 degrees F.), and to a dark red at higher temperatures. Taste, smooth and fat. When ground to 20-mesh and mixed with 38.0 per cent of water, it made a fairly plastic paste, that stood rapid drying, and that shrank 8.0 per cent in drying and 5.0 per cent additional when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 94 pounds to the square inch, as the average of seven tests, with a maximum strength of 109 pounds. Incipient vitrification occurred below cone 1 (2,102 degrees F.), and complete at cone 6 (2,282 degrees F.). This clay may prove suited to the manufacture of paving brick.

CLAY No. 121. (Chemist's No. 3134.) First Cut west of great fill, one mile west of Indian Fields, Clark county, Ky. Estill clay; middle Niagara Clay.

Sample consisted of a few rather thin pieces of yellowish clay shale. Fusible and plastic. Not an average sample.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.73
Combined water	6.08
Carbon dioxide	0.51
Silica	55.68
Alumina	21.08
Ferric oxide	1.92
Ferrous oxide	3.52
Calcium oxide	1.78
Magnesium oxide	2.35
Potassium oxide	4.88
Sodium oxide	0.50
Titanium dioxide	0.50
Sulphur trioxide	tr.
Phosphoric acid	tr.
Total	100.53

The analysis of the clay shows that it could be used for making brick, drain tiles, etc.

The sample of this clay gave the following characteristics: Color, green; burned dark brown. Taste, fat and smooth. Texture, soft, fine-grained, uniform. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that stool rapid drying and that shrank 8.0 per cent in drying. The clay reached viscosity at cone 6 (2,282 degrees F.). It is a low-grade, common-brick clay.

CLAY No. 119. (Chemist's No. 3136.) Hornback Curve, west of Indian Fields, Clark county, Ky. Top of the Upper Richmond: 0-10 feet below Clinton.

The sample consisted of a small quantity of slightly greenish looking clay shale containing carbonates.

Analysis of Air-dried Sample:

	Per cent.
Moisture	1.07
Combined water and carbon dioxide	17.23
Silica	44.74
Alumina	14.02
Ferric oxide	1.92
Ferrous oxide	1.87
Calcium oxide	10.18
Magnesium oxide	7.10
Potassium oxide	1.93
Sodium oxide	0.18
Titanium dioxide	0.40
Sulphur trioxide	tr.
Phosphoric acid	tr.
Total	100.64
Ratio of Iron and Alumina to Silica	2.47

The sample of this clay gave the following characteristics: Color, green; burned brown. Taste, fat and smooth. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 23.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying and an equal amount when vitrified, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 55 pounds to the square inch. Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 3 (2,174 degrees F.), viscosity at cone 6 (2,282 degrees F.). This is a low-grade clay.

CRITTENDEN COUNTY.

CLAY No. 160. (Chemist's No. 3304.)

Clay sent by the Pope Mining Company, of Louisville, Ky. The clay occurs in a fissure vein and is surrounded by sandstone.

The sample consisted of a few small lumps of clay colored purplish by iron oxide.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.74
Combined water, etc.	6.72
Silica	58.50
Alumina	23.40
Ferric oxide	3.20
Ferrous oxide	tr.
Calcium oxide	0.32
Magnesium oxide	1.52
Potassium oxide	4.39
Sodium oxide	0.23
Titanium dioxide	0.80
Sulphur trioxide	tr.
Total	100.82

The analysis shows that the clay is only of medium quality. It would not be very refractory. It can be readily fused in the blow-pipe flame. Tests made with the clay showed none of the properties of a Fullers' Earth.

The sample of this clay gave the following: Color, bluish white, burned brown. Taste, very fat and smooth. When ground to 20-mesh and mixed with 33.0 per cent of water, it made an exceedingly plastic paste, that stood rapid drying and that shrank 7.0 per cent in drying and 6.0 per cent more when vitrified, giving a total shrinkage of 13.0 per cent. Sample too small to test tensile strength. Complete vitrification occurred at cone 1 (2,102 degrees F.), with very little change at cone 9 (2,390 degrees F.). This is a fair stone-ware clay.

CLAY No. 145. The Tanner Clay.—North Pit. This clay is on the C. W. Bryant place, which is on the Marion and Salem Road, about three miles west of Marion. The clay occurs along a dike.

The following analysis of this clay is given in Bulletin No. 6 of the Kentucky Geological Survey: No. 1295—Soft, powdery, nearly white clay, from the farm of C. W. Bryant, three miles southwest of Marion. A sample pitcher was made of this clay by the Brockman Pottery Company, Cincinnati, O. The glazed ware is white, with a faintly bluish tinge. Analysis by A. M. Peter.

Composition, Air-dried:

	Per cent.
Moisture	1.36
Ignition	9.78
Silica	57.56
Alumina	30.47
Ferric oxide	tr.
Lime	0.30
Magnesia	0.24
Potash	0.26
Soda	0.20
Sulphuric anhydride	tr.
Total	100.17

A sample of this clay, which seems not to be the same deposit given above under the number 12,950, gave the following characteristics: Color, when mixed, yellow; pinkish-gray at cone 7 (2,318 degrees F.), becoming more nearly gray, with less pinkish tint at cone 9 (2,390 degrees F.). Taste, lean and gritty. When ground to 20-mesh and mixed with 41.0 per cent of water, it made a rather lean paste, that shrank 7.5 per cent in drying and an additional 10.0 per cent at cone 11 (2,462 degrees F.), giving a total shrinkage of 17.5 per cent. The air-dried mud showed a tensile strength of 29 pounds to the square inch, as the average of four tests, with a maximum strength of 39 pounds. There was no indication of vitrification at cone 11 (2,462 degrees F.)

This is an impure kaolin which burns to an undesirable color.

CLAY.—No. 45. This clay represents decomposed dike material from the farm of C. W. Bryant, as described above under Clay No. 145.

The sample gave the following: Color, yellowish brown, more nearly brown when wet; burned, the color became reddish-brown to gun-metal blue. Taste, fat, gritty. Texture, soft, coarse-grained. When ground to 30-mesh and mixed with 38.0 per cent of water, it made a fat paste that stood rapid drying, and that shrank 9.0 per cent in drying and 3.0 per cent additional in burning to vitrification, giving a total shrinkage of 12.0 per cent. The air-dried mud showed a tensile strength of 147.2 pounds to the square inch, as the average of five tests, with a maximum strength of 186.8 pounds. Complete vitrification occurred at cone 6 (2,282 degrees F.). This should make common brick.

CLAY No. 44. Another Tanner Clay. (See Clay No. 145 above.)

A sample of this clay was labeled, "Marion and Salem Road, three miles west of Marion, along dike, on farm of C. W. Bryant. Tanner deposit, Pit No. 1." This sample gave the following characteristics: Color, nearly white, with slight yellowish tint; burned more nearly white. Texture, soft, fine-grained, massive, uniform. Taste, lean and slightly gritty. When ground to 30-mesh and mixed with 40.0 per cent of water, it made a lean paste, that stood rapid drying, and that shrank 7.0 per cent in drying and 6.0 per cent additional in burning to cone 7 (2,318 degrees F.), giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 32 pounds to the square inch, as the average of five tests; all five tests gave the same result. The clay burned to a hard, compact body without warping when in thin plates. There was slight indication of vitrification at cone 7 (2,318 degrees F.). This is a high-grade clay suited to the manufacture of white-burning pressed brick, pottery, etc.

CUMBERLAND COUNTY.

CLAY No. 92. "Shale from the basal four and one-half feet of Keokuk-Waverley. To be analyzed and report sent to James McMurtry, Burkesville Hill, Cumberland County, Ky."

The sample consisted of thin chips of shale. Fusible in the blow-pipe flame.

Analysis of Air-Dried Sample.

	Per Cent.
Moisture at 100° C.	1.24
Combined water and carbonaceous matter	4.68
Silica	67.82
Alumina	15.35
Ferric oxide	2.64
Ferrous oxide	1.58
Calcium oxide	tr.
Magnesium oxide	1.84
Potassium oxide	3.57
Sodium oxide	0.06
Titanium dioxide	0.35
Sulphur trioxide	tr.
Phosphoric acid	none
Total	99.13
Ratio of Iron and Alumina to Silica	3.43

The analysis shows that this clay is suited for making Portland Cement in connection with pure limestone.

The sample of this clay gave the following characteristics: Color, green; burned to a bright red, changing to very dark reddish-brown. Taste, lean. Texture, soft and coarse-grained. When ground to 20-mesh and mixed with 15.0 per cent of water, it made a lean paste, lacking in plasticity, that shrank 2.0 per cent in drying and 4.0 per cent additional when vitrified, gaving a total shrinkage of 6.0 per cent. The air-dried mud showed a tensile strength of only 16 pounds to the square inch. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 5 (2,246 degrees F.).

This is a good grade of common brick and tile clay.

EDMONSON COUNTY.

CLAY No. 78. The John Wells place. This farm is on the Brownsville and Bowling Green Road, three miles southeast of Brownsville. At this place there is a thin stratum of coal underlaid by dark clay which occur in the Chester Group near the top. This is a very persist-

ant coal and clay; the two are exposed at numerous places over the county.

A typical exposure at this coal is shown in the following section, reading downward:

1.	White sandstone	20 ft.
2.	Brown, grained limestone	5 ft.
3.	Dark shale	6 in.
4.	"Dark, shaly clay"	2 ft.
5.	Coal	1 in.
6.	Dark, shaly clay	3 ft.
7.	Covered	10 ft.
8.	Sandstone	20 ft.

This material is on the order of a clayey shale and to some extent resembles a fire clay. It contains a vast amount of impurities and is easily fused. The clay is apparently the same above the coal as below.*

A sample of this clay gave the following characterastics: Color, dark gray; burned to brown. Taste, exceedingly lean and gritty. Texture, hard, coarse-grained, shaly. When ground to 30-mesh and mixed with 25.0 per cent of water, it made a paste rather low in plasticity, that stood rapid drying, and that shrank 5.0 per cent in drying and 4.0 per cent additional when vitrified, giving a total shrinkage of 9.0 per cent. The air-dried mud showed a tensile strength of 60 pounds to the square inch, as the average of ten tests, with a maximum strength of 68 pounds. The clay was fully vitrified at cone 2 (2,138 degrees F.), and partially viscous at cone 6 (2,282 degrees F.).

This is a low-grade clay of little or no value for the manufacture of clay products.

CLAY No. 77. The W. B. Parsley place. This place is about five miles northeast of Brownsville and three miles from the mouth of Nolin River.

On this place there is a deposit of clay exposed in a ditch about fifty yards long. This ditch was made in search for asphalt rock, but not dug to sufficient depth to expose anything but soil and clay.

The following is a section here:

*Ky. Geol. Survey, Bull. No. 6, p. 49.

1.	Soil	3	ft.
2.	Light colored plastic clay	3½	ft.
3.	Covered	10	ft.
4.	Chester sandstone (bituminous)	4	ft.

In this sandstone exposure there are signs of asphalt, but considerable work is necessary to show whether or not it is present in paying quantity.

An analysis of the clay is as follows:

	Per Cent.
Moisture	1.79
Ignition (combined water and volatile matter)	6.36
Silica	64.36
Alumina	20.90
Ferric oxide	1.39
Lime	0.40
Magnesia	0.69
Potash	1.88
Soda	0.17
Titanium dioxide	1.32
Phosphorous pentoxide	0.06
Sulphur trioxide	tr.
Total	99.32

Remarks by the chemist: "This clay should be quite refractory, and, being quite sandy, should shrink very little in burning."*

A sample of this clay gave the following characteristics: Color, gray, red and yellow; mixed, it was pale yellow; burned to reddish yellow. Taste, lean, and very gritty. Texture, soft, coarse-grained. When ground to 20-mesh and mixed with 31.5 per cent of water, it made a rather lean paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 12.0 per cent additional in burning, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strength of 80 pounds to the square inch, as the average of five tests, with a maximum strength of 90 pounds. It burned to a hard, compact body, free from warping when in thin slabs. Incipient vitrification occurred at cone 5 (2,246 degrees F.), and not complete at cone 9 (2,390 degrees F.).

Ky. Geol. Surv., Bull. No. 6, p. 53.

This is a semi-refractory clay of an excellent quality. It would not work very well on a potter's wheel, but, by the addition of a small proportion of a more plastic clay, it could be brought to the proper physical degree of plasticity and toughness to make excellent stoneware. It would make a good grade of terra cotta, giving a desirable color to the body.

CLAY No. 76. Mr. Bennett Lindsay place. This land is about one-fourth of a mile west of Brownsville, Edmonson county, Ky. Here a yellow plastic clay occurs at the Base of the Conglomerate.

A sample of this clay gave the following characteristics: Color, yellow; brownish yellow when mixed; burned to a dark red. Taste, slightly fat and gritty. Texture, soft, coarse-grained, compact. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a moderately plastic paste, that required very slow drying, and that shrank 10.0 per cent in drying and 16.0 per cent additional when vitrified, giving a total shrinkage of 26.0 per cent. It warped and cracked somewhat in burning. Complete vitrification occurred at cone 6 (2,282 degrees F.). This is a low-grade common-brick clay.

CLAY No. 56. The John T. B. Stice place. Mr. Stice's farm is on a small neighborhood road one and a half miles south of Brownsville on the east bank of Green River. At the east side of his farm, one-half a mile from the river, there is an interesting deposit. Here there is a long hollow with bold ridges on either side. Along these ridges, at the base of Conglomerate cliffs, there are outcroppings of small white pieces of clay. At one point a pit was dug into this material to the depth of seven feet. Beneath the surface the pieces were more waxy in appearance. Deeper down the material becomes brown and hard, resembling bauxite.

Analyses have proven this waxy material with a smooth conchoidal fracture and the white particles above it to resemble indianaite, and the material below to be a mixture of bauxite and wavellite. The one changes very gradually into the other.

The following is a section at this exposure:

Conglomerate sandstone	70 ft.
White particles	1 ft.
Yellow and waxy (indianaite)	4 ft.
Mixture bauxite and wavellite	2 ft.
Covered	10 ft.
Kaskaskia limestone	2 ft.

The material is stained with iron oxide to some extent on the outside of the pieces. The indianaite is found in pieces from the size of a bird's egg to six inches in diameter. The mixture of bauxite and wavellite occurs in chunks or boulders from six inches to a foot thick.

Following is the analysis of the white material at the top:

	Per cent.
Moisture	5.15
Ignition (combined water and volatile matter)	14.52
Silica	42.40
Alumina	36.21
Ferric oxide	0.45
Lime	0.38
Magnesia	0.53
Potash	0.09
Soda	0.08
Phosphorus pentoxide	0.20
Titanium dioxide	tr.
Sulphur trioxide	tr.
Total	100.01

Following is the analysis of the waxy material:

	Per cent.
Moisture	6.84
Ignition (combined water and volatile matter)	13.84
Silica	42.42
Alumina	35.20
Ferric oxide	0.64
Lime	0.34
Magnesia	0.53
Potash	0.23
Soda	0.09
Phosphorus pentoxide	0.22
Titanium dioxide and sulphur trioxide	traces
Total	100.35

Following are Dr. Peter's comments: "This has substantially the same composition as the white material of the first analysis. The analyses are close to those of the indianaite of E. T. Cox."

An analysis of the hard brownish material at the bottom is as follows:

	Per cent.
Moisture	13.65
Ignition (combined water and volatile matter)	20.92
Silica	20.04
Alumina	40.53
Ferric oxide	1.24
Lime	0.36
Magnesia	0.40
Potash	0.31
Soda	none
Phosphorus pentoxide	3.75
Titanium dioxide	tr.
Sulphur trioxide	0.27
Total	101.47

Dr. Peter comments on the material as follows: "Possibly a mixture of bauxite and wavellite. The material is interesting and deserves further study."*

A sample from this deposit gave the following characteristics. Color, when ground and mixed, yellowish-gray; became a pinkish-white with dark specks when burned. Taste, lean and gritty. Texture, hard, coarse-grained and fine-grained irregular. When ground to 30-mesh and mixed with 25.0 per cent of water, it made an exceedingly lean paste, almost wholly wanting in plasticity. This paste shrank almost none in drying, and 7.0 per cent in burning to cone 7 (2,318 degrees F.). At cone 11 (2,462 degrees F.) there was no indication of vitrification and the clay remained crumbly. This is a good grade of nearly white-burning refractory clay, but requires the addition of some other clay to give proper bonding.

CLAY No. 48. This clay is on the D. H. Johnson place, four miles southeast of Brownsville, Edmonson

*Ky. Geol. Surv., Bull. No. 6, p. 50-52.

county, along the Brownsville and Bowling Green Road. Geological position, Kaskaskia.

A sample of this clay gave the following characteristics. Color, variegated, yellow, red and drab; the color was drab when mixed; the color became green when burned. Taste, fat, slightly sour, and very gritty. Texture, soft, coarse-grained and fine-grained. When ground to 30-mesh and mixed with 30.0 per cent of water, it made a plastic paste, that required exceedingly slow drying in order to prevent cracking. The clay shrank 8.0 per cent in drying and 5.0 per cent more when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud had a tensile strength of 43.5 pounds to the square inch, as shown by two tests only, each giving the same strength. Complete vitrification occurred at cone 5 (2,246 degrees F.). This clay cracks badly in burning and has very little value.

FAYETTE COUNTY.

CLAY No. 47. S. W. Wickline Farm. A plastic clay occurs in a cut along the C. & O. R. R. two miles east of Lexington, Fayette county, on the farm of Mr. S. W. Wickline. This clay is a residual from Eden Shale, resting on Lexington Limestone, and shows a thickness of sixteen feet.

A sample of this clay gave the following characteristics: Color, yellow and green with black spots; ground and mixed, the color was brownish-yellow; burned, dark red, becoming almost brown when vitrified. Taste, fat and a little gritty, slightly sour. Texture, soft, rather coarse-grained, irregular. When ground to 30-mesh and mixed with 32.0 per cent of water it made a plastic paste, that required care in drying, and that shrank 8.0 per cent in drying with an additional 5.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. Complete vitrification occurred at cone 5 (2,246 degrees F.). This is a low-grade clay.

FULTON COUNTY.

CLAY No. 16. This clay shows a thickness of thirty feet and occurs along the Mississippi River bluffs just

above the tracks of the N. C. & St. L. R. R. on the north side of the town of Hickman, Fulton county. Ky.

This is Clay No. 1 in the following section:

No. 9 Clay.	Greenish, plastic	4 to 6 ft.
No. 8 Clay.	Greenish, sandy, undulated	1 to 12 ft.
No. 7 Clay.	Slate colored, hard, containing ferruginous streaks	3 ft.
No. 6 Clay.	Greenish, sandy, soft	3 ft.
No. 5 Clay.	Greenish, slightly sandy, soft	3 ft.
No. 4 Clay.	Greenish, sandy, plastic	4 to 8 ft.
No. 3 Clay.	Slate colored, hard, containing in lower eight inches of bed small veins of opalescent quartz	6 to 8 ft.
No. 2 Clay.	Grayish, plastic	1 to 2 ft.
No. 1 Clay.	Grayish, semi-plastic, with ferruginous streaks; upper thirty feet sampled	50 ft.

Geological position, Hickman Formation, Eocene Series, Tertiary System.

The sample of this clay gave the following characteristics: Color, green when dry, darker green when wet; when burned to cone 1 (2,102 degrees F.), it became a bright yellow, but changed to dark red at higher temperatures. Texture, soft, fine-grained. Taste, fat and no grit. When ground to 20-mesh and mixed with 28.0 per cent of water, it made a very fat paste, that shrank 9.0 per cent in drying and 6.0 per cent more in burning, giving a total shrinkage of 15.0 per cent. It required very slow drying and cracked badly in burning. The air-dried mud showed a tensile strength of 206 pounds to the square inch, as the average of four tests, with a maximum strength of 220 pounds. This is a low-grade clay poorly suited to the manufacture of common brick and tile.

CLAY No. 18. This is Clay No. 7 in the section given above under Clay No. 16. The sample gave the following: Color, pale yellow to greenish-gray when dry, and greenish-gray when wet; when burned to cone 1 (2,102 degrees F.), it became a bright yellow, becoming a dark red at higher temperatures. When ground to 20-mesh and mixed with 22.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and 4.0 per cent more in burning, giving a total shrinkage of 12.0 per cent.

It required slow drying. The tensile strength, as shown by the average of sixteen tests, was 189.5 pounds to the square inch, with a maximum strength of 260.8 pounds. Vitrification was complete at cone 7 (2,318 degrees F.). This is a low-grade clay.

CLAY No. 20. This is Clay No. 6 in the section given above under Clay No. 16. The sample gave the following characteristics: Color, green, both wet and dry; it became bright yellow when burned to cone 1 (2,102 degrees F.), and dark red at higher temperatures. Taste, fairly fat, and gritty.

When ground to 20-mesh and mixed with 20.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and 2.0 per cent more in burning, giving a total shrinkage of 10.0 per cent. The tensile strength, as shown by sixteen tests, averaged 172.8 pounds to the square inch, with a maximum strength of 212 pounds. Vitrification not complete at cone 7 (2,318 degrees F.). This is a low-grade clay very like Clay No. 18.

CLAY No. 22. This represents a mixture of equal parts of Clay No. 18 and Clay No. 20 and gave characteristics like the individual members. It is of very little commercial value.

GRAVES COUNTY.

CLAY No. 100. Clay from near Pottery, operated by W. B. Howard & Son, eighteen miles southeast of Mayfield, Graves county, Ky., on the Mayfield and Paris Road. Thickness ten feet. Base of Quaternary.

Sample consisted of one large and a few irregular sized lumps, with some fine clay material of gray color. The clay contained nodules of iron oxide and pieces of sandstone, which were excluded.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.10
Combined water	6.25
Silica	68.54
Alumina	19.92
Ferric oxide	0.80
Ferrous oxide	tr.

	Per cent.
Calcium oxide	tr.
Magnesium oxide	0.70
Titanium dioxide	1.20
Potassium oxide	1.66
Sodium oxide	0.24
Sulphur trioxide	none
Phosphoric acid	none
Total	100.41
Ratio of Silica to Alumina and Iron	3.30

The analysis shows that this clay is suitable for making Portland Cement, if not too sandy. It should be an excellent siliceous fire clay.

A sample of this clay gave the following characteristics: Color, almost white; burned almost white up to cone 1 (2,102 degrees F.), becoming more of a gray at higher temperatures. Taste, fat, and some grit. When ground to 20-mesh and mixed with 27.0 per cent of water, it made a very plastic paste, that shrank 5.0 per cent in drying and an additional 9.0 per cent when burned to cone 9 (2,390 degrees F.). The air-dried mud showed a tensile strength of only 25 pounds to the square inch. The clay burned to a hard, compact body. Incipient vitrification occurred at cone 7 (2,318 degrees F.), complete at cone 11 (2,462 degrees F.).

This is a high-grade semi-refractory clay.

CLAY No. 120. Wm. P. Arnett Clay. Exposed on Panther Creek, Mayfield and Wadesboro Road, six miles east of Mayfield, Graves county, Ky. Thickness, four feet. Base of Quaternary. Stratified drift.

Sample consisted of irregular sized lumps of light blue clay containing considerable sand.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	0.61
Combined water	7.15
Silica	69.72
Alumina	17.80
Ferric oxide	1.28
Ferrous oxide	0.43
Calcium oxide	tr.

	Per cent.
Magnesium oxide	0.90
Titanium dioxide	0.70
Potassium oxide	1.00
Sodium oxide	0.48
Total	100.07
Ratio of Silica to Alumina and Iron	3.56

Rather too siliceous for making Portland Cement unless the sand could be washed out. It should be a good siliceous fire clay.

A sample of this clay gave the following characteristics: Color, dark gray; burned to a slightly yellowish-gray. Taste, fat and smooth, very little grit. Texture, soft, coarse and fine-grained. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 6.0 per cent in drying and an additional 7.0 per cent in burning to cone 9 (2,390 degrees F.), giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 34 pounds to the square inch. Incipient vitrification occurred at cone 5 (2,246 degrees F.), complete at cone 10 (2,426 degrees F.).

This is a high-grade semi-refractory clay.

KENTUCKY CONSTRUCTION & IMPROVEMENT COMPANY CLAYS. This firm is located at Mayfield, Graves county, Ky. They have a bank of plastic clay thirty-two feet thick, with a heavy strata of lignite covering the whole. The clay is not in beds, but is in one solid bank, divided into stratas as follows:

Strata No. 2	3 ft. thick.	(Clay No. 155.)
Strata No. 3	3 ft. thick.	(No. sample.)
Strata No. 4	4 ft. thick.	(Clay No. 156.)
Strata No. 5	4 ft. thick.	(Clay No. 158.)

Stratas No. 1 and No. 6 are included in the thirty-two feet, but no samples of these were received.

CLAY No. 155. (Chemist's No. 3307.) "Ball-clay sent by the Kentucky Construction & Improvement Company, of Mayfield, Graves county, Ky. Oliver No. 2; strata No. 2 is three feet thick."

The sample consisted of about twenty-five pounds of rather large sized lumps of gray clay having a soapy feel and containing some streaks of lignite.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	2.13
Combined water, etc.	11.66
Silica	51.92
Alumina	30.36
Ferric oxide	1.60
Ferrous oxide	tr.
Calcium oxide	0.32
Magnesium oxide	tr.
Potassium oxide	1.28
Sodium oxide	0.45
Titanium dioxide	1.00
Sulphur trioxide	none
Total	100.72

The analysis shows that this clay should be quite refractory, and tests made in the blow-pipe flame showed that the clay was infusible at that temperature.

The sample of this clay gave the following characteristics: Color, light gray; burned nearly white at cone 6 (2,282 degrees F.), becoming more of a gray at higher temperatures. Taste, fat and smooth. Texture, soft, fine-grained, massive, uniform. When ground to 20-mesh and mixed with 44.0 per cent of water, it made an exceedingly plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and an additional 10.0 per cent when vitrified, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strength of 60 pounds to the square inch, as the average of eight tests, with a maximum strength of 78 pounds. Incipient vitrification occurred at cone 2 (2,138 degrees F.), complete at cone 7 (2,318 degrees F.). It burned to a hard, compact body. This is an excellent clay and should make a superior grade of pressed brick.

CLAY No. 156. (Chemist's No. 3308.) "Ball-clay sent by the Kentucky Construction & Improvement Company, of Mayfield, Graves county, Ky. Oliver No. 4; thickness of strata, four feet."

The sample consisted of rather large sized lumps of gray clay having a soapy feel and containing some lignite.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.45
Combined water, etc.	10.74
Silica	57.72
Alumina	24.84
Ferric oxide	1.44
Ferrous oxide	tr.
Calcium oxide	0.38
Magnesium oxide	tr.
Potassium oxide	0.92
Sodium oxide	0.28
Titanium dioxide	2.20
Sulphur trioxide	tr.
Total	99.97

The analysis shows that this is a very refractory clay. It was infusible in the blow-pipe flame.

The sample of this clay gave the following characteristics: Color, gray; burned almost white. Taste, fat, and smooth. Texture, soft, fine-grained, compact, uniform. When ground to 20-mesh and mixed with 40.0 per cent of water, it made a very plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 8.0 per cent more when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 54 pounds to the square inch, as the average of six tests, with a maximum strength of 67 pounds. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 9 (2,390 degrees F.). It burned to a hard, compact body, and should be well suited to the manufacture of a beautiful pressed brick.

CLAY No. 158. (Chemist's No. 3310.) "Ball-clay sent by the Kentucky Construction & Improvement Company, of Mayfield, Graves county, Ky. Oliver No. 5; five feet thick."

The sample consisted of rather large sized lumps of light-colored clay, having a soapy feel. No lignite observed in the sample.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.32
Combined water, etc.	9.89
Silica	53.76
Alumina	29.04
Ferric oxide	1.12
Ferrous oxide	tr.
Calcium oxide	1.32
Magnesium oxide	tr.
Potassium oxide	0.99
Sodium oxide	0.31
Titanium dioxide	1.80
Sulphur trioxide	tr.
Total	99.55

The analysis shows that this clay should be refractory in the fire. It was infusible in the blow-pipe flame.

The sample of this clay gave the following characteristics: Color, very light gray; burned nearly white at cone 1 (2,102 degrees F.), more gray at higher temperatures, but remaining very light colored. Taste, fat, and smooth. Texture, soft, fine-grained, compact, massive, uniform. When ground to 20-mesh and mixed with 38.0 per cent of water, it made a plastic paste, that shrank 3.0 per cent in drying and 7.0 per cent more when vitrified, giving a total shrinkage of 10.0 per cent. It stood rapid drying.

The air-dried mud showed a tensile strength of 40 pounds to the square inch, as the average of six tests, with a maximum strength of 60 pounds. It burned to a hard, compact body. Incipient vitrification occurred at cone 01 (2.066 degrees F.), complete at cone 6 (2,282 degrees F.).

CLAY No. 157. (Chemist's No. 3309.) "Ball-clay sent by the Kentucky Construction & Improvement Company, of Mayfield, Graves county, Ky. Old mine No. 4. Thickness of strata, three feet six inches."

The sample consisted of rather large size lumps of gray clay, having a soapy feel. Contained some lignite, but less than Nos. 3307 and 3308.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.91
Combined water, etc.	12.40
Silica	49.32
Alumina	32.64
Ferric oxide	1.44
Ferrous oxide	tr.
Calcium oxide	0.34
Magnesium oxide	tr.
Potassium oxide	1.03
Sodium oxide	0.29
Titanium dioxide	1.00
Sulphur trioxide	tr.
Total	100.37

The analysis shows that this should be a very refractory clay, probably more so than either of the other samples. It was infusible in the blow-pipe flame.

The sample of this clay gave the following characteristics: Color, gray; burned almost white at cone 1 (2,102 degrees F.), turning to gray at higher temperatures. Taste, fat, and smooth. Texture, soft, fine-grained, compact and uniform. When ground to 20-mesh and mixed with 48.0 per cent of water, it made a very plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and an additional 10.0 per cent when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 51 pounds to the square inch, as the average of ten tests, with a maximum strength of 63 pounds. Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 6 (2,282 degrees F.). It burned to a good body. This should make an excellent pressed brick.

CLAY No. 10. Mr. P. Burnett Place. A sample of this clay was brought and represents the upper fifteen inches of a bed reported to be from nine to twenty feet thick. It occurs on the farm of Mr. P. Burnett three miles northeast of Mayfield, Graves county, Ky. The geological position is Wilcox Formation, Eocene Series, Tertiary System.

When tested, this clay gave the following characteristics: Color, when dry, nearly white, becoming light gray when wet; burned to cone 1 (2,102 degrees F.), the color was nearly white with a slightly pinkish tint, becoming a muddy cream up to cone 6 (2,282 degrees F.), and gray at higher temperatures. This is a soft, fine-grained, uniform clay that left a few sharp, clear quartz grains on the 100-mesh sieve after disintegration by prolonged shaking in water.

When ground to 20-mesh and mixed with 29.0 per cent of water, it made an exceedingly plastic paste, that shrank 7.0 per cent in drying and a like amount in burning, giving a total shrinkage of 14.0 per cent. The tensile strength, as shown by the average of two tests only, was 48.4 pounds to the square inch, with a maximum of 52 pounds. Incipient vitrification occurred at cone 7 (2.318 degrees F.), complete at cone 10 (2,426 degrees F.).

This clay will make beautiful pinkish white brick if burned at low temperatures.

GRAYSON COUNTY.

CLAY No. 126. The Garten Petty Place. Mr. Petty's farm is just west of the I. C. R. R., one-half mile north of Big Clifty. About one hundred yards west of the railroad, on the southern part of the farm, there is a small spring which issues above a deposit of impure, plastic clay. The exposure is very slight in its vertical extent, but shows at various places around a large hill. The following is the section here:

1.	Brown sandstone	25 ft.
2.	Drab, plastic clay	3½ ft.
3.	Gray limestone	10 ft.
4.	Big Clifty sandstone (covered).	

This clay does not present a favorable appearance, being a mixture of clay, soil and organic matter near the top. This clay might be used, however, for low-grade earthenware, etc.*

*Ky. Geol. Surv., Bull. No. 6, p. 62.

A sample of this clay gave the following characteristics: Color, green; burned dark red. Taste, fat, very little grit. When ground to 20-mesh and mixed with 24.0 per cent of water, it made a plastic paste, that stood a fair rate of drying, and that shrank 10.0 per cent in drying and an additional 5.0 per cent. when vitrified, giving a total shrinkage of 15.0 per cent. The tensile strength was rather low. Complete vitrification occurred at cone 01 (2,066 degrees F.). This is a common brick clay of fair quality.

GRANT COUNTY.

CLAY No. 90. (Chemist's No. 3133.) Clay from first railroad cut north of Mason, Grant county, Ky. Upper Utica. Average sample of yellow calcareous shale, containing fire-clay material. Fusible before the blow-pipe.

Analysis of Air-Dried Sample.

	Per cent.
Moisture	2.00
Combined water and CO_2	9.01
Silica	52.50
Alumina	16.87
Ferric oxide	5.28
Ferrous oxide	1.01
Lime	3.04
Magnesium Oxide	2.06
Potassium oxide	5.67
Sodium oxide	1.44
Titanium dioxide	0.50
Sulphur trioxide	none
Phosphoric acid	0.33
Total	99.71
Ratio of iron and alumina to silica	2.22

A sample of this clay gave the following characteristics: Color, green; burned to dark reddish brown when vitrified and almost black when fused. Taste, fat, and rather free from grit. When ground to 20-mesh and mixed with 34.0 per cent of water, it made a plastic paste, that stood moderately rapid drying, and that shrank 8.0 per cent in drying and 5.0 per cent more when

vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 74 pounds to the square inch, only one test being made, but this gave a good fracture. The clay was fully vitrified at cone 01 (2,066 degrees F.), and reached viscosity at cone 5 (2,246 degrees F.). This is a low-grade clay.

GREEN COUNTY.

CLAY No. 102. (Chemist's No. 3144.) "One mile east of Powder Mills. Top St. Louis. Bayler Perkins & John Dobson—fourteen acre lake."

Sample consisted of borings of yellow clay containing some white clay and some particles of iron oxide.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.95
Combined water	6.21
Silica	66.68
Alumina	15.38
Ferric oxide	5.76
Ferrous oxide	none
Calcium oxide	0.16
Magnesium oxide	1.63
Titanium dioxide	0.50
Potassium oxide	1.85
Sodium oxide	0.31
Sulphur trioxide	none
Phosporic acid	none
Total	100.43

The analysis shows that the composition is right for a Portland Cement clay. It is fusible in the blow-pipe flame.

A sample of this clay gave the following characteristics: Color, yellow; burned to a dark red when vitrified. Taste, fat, and gritty. Texture, soft and coarse-grained. When ground to 20-mesh and mixed with 25.0 per cent water, it made a plastic paste, that shrank 7.0 per cent in drying and 8.0 per cent additional when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 138 pounds to the

square inch. Incipient vitrification occurred at cone 2 (2,138 degrees F.), complete at cone 7 (2,318 degrees F.). This is a good common-brick and tile clay.

HART COUNTY.

CLAY No. 9. The Moss Kaolin Field. What is here termed the "Moss Kaolin Field" is an area of several thousand acres in which kaolin outcroppings and exposures are found. It is so designated because the most important and original exposure is on the land of Mr. Philip Moss.

Over this field we find the Conglomerate Sandstone immediately above the clay and the St. Louis Limestone only a few feet below.

Mr. Moss lives on a neighborhood road to Bonnieville, about five miles southeast of that town. On his farm there are two important exposures. The first is just west of his house, and here a semi-circular pit has been dug about one hundred feet long and ten feet deep, which gives a good exposure of the deposit.

The following is a section here:

Conglomerate sandstone	20	ft.
Pink clay and ochre	4	in.
Very white kaolin	8	in.
Brown stained kaolin	13	ft.
Coal	3½	in.
Fire clay	?	

The St. Louis Limestone evidently occurs only a short depth below the under clay, called "fire clay," as shown by its level at other places. It is not exposed at this point.

Experiments have proven this white kaolin to be an excellent quality of clay for the manufacture of fine china ware and porcelain.

Following is an analysis of the unwashed kaolin from the shaft on the Philip Moss place:

	Per cent.
Moisture	2.39
Ignition	12.68
Silica	48.09
Alumina	34.66
Ferric oxide	0.78
Lime	0.27
Magnesia	0.23
Potash	0.74
Soda	0.30
Titanic oxide	0.25
Total	100.39

The foregoing analysis is of an average sample from exposure No. 1.

Following is an analysis of an average sample taken from the long pit. Sample mostly white, soft and very porous. One piece was much stained by iron.

Analysis of Air Dried Sample.

	Per cent.
Moisture	2.71
Ignition	16.69
Silica	42.32
Alumina	36.92
Ferric oxide	0.62
Lime	0.21
Magnesia	0.08
Potash	0.47
Soda	0.18
Titanic oxide	tr.
Sulphuric anhydride	tr.
Total	100.25(*)

A sample of this clay contained pure-white kaolin. pink kaolin and ochre. (For tests of the pure-white kaolin see Clay No. 24, following.)

This sample, when ground and mixed, gave the following characteristics: Color, when dry, reddish-pink with white, black and red specks; darker red when wet; when burned to cone 1 (2,102 degrees F.), the color had

*Ky. Geol. Surv.. Bull. No. 6, p. 31-33.

changed but little from what it was when dry; at cone 6 (2,282 degrees F.), the color was pale pink with white specks; at cone 9 (2,390 degrees F.), the color was mottled gray with white and black specks. Taste, somewhat fat, and free from grit. Texture, soft, fine-grained and massive.

When ground to 20-mesh and mixed with 48.0 per cent of water, it made a somewhat plastic paste, that stood rapid drying, and that shrank 6.0 per cent in drying and 17.0 per cent more in burning, giving a total shrinkage of 23.0 per cent. The tensile strength, as shown by the average of twelve tests, was 67.3 pounds to the square inch, with a maximum strength of 85.1 pounds. There was no evidence of vitrification at cone 9 (2,390 degrees F.).

The color of this mixture is very bad and it would not have any value for high-grade chinaware.

CLAY NO. 24. White Kaolin. This represents the pure-white portion of the sample just described under Clay No. 9, and, in sufficient quantity, it would be one of the very best grades of kaolin for the manufacture of fine chinaware and porcelain, but the deposit is not of such extent as to be of value commercially.

The sample gave the following characteristics: Color, pure white, remaining so at all temperatures. Taste, somewhat fat and no grit. When ground to 20-mesh and mixed with 68.0 per cent of water, it made a fair paste, that shrank 7.0 per cent in drying and only 5.0 per cent more in burning to cone 9 (2,390 degrees F.), giving a total shrinkage of 12.0 per cent. The tensile strength, as shown by a single test of the air-dried mud, was 69.1 pounds to the square inch. This is a highly refractory clay.

CLAY NO. 25. Kaolin from the S. J. Murray Place. The farm of Mr. S. J. Murray is on a country road or "Shun Pike," from Bonnieville to Munfordville, three miles from Bonnieville.

A valuable deposit of kaolin has been exposed on this place by a shaft about fifteen feet deep. The section here is as follows:

Soil	2 ft.
Soil, sand and clay	3 ft.
Stained kaolin	3 ft. 10 in.
White kaolin	1 ft.
Stained kaolin	0 10 in.

No limestone nor sandstone is exposed at this point, but, according to aneroid readings, the deposit is just above the St. Louis Limestone. The clay termed "stained kaolin" is slightly colored yellowish with iron oxide; probably not to such an extent, however, that it cannot be washed white, or will not burn white. These purest white layers contain no injurious impurities and require no admixture of foreign material in order to make it suitable for the manufacture of fine porcelain or china-ware.

The hillsides over an area of four or five acres show signs of this deposit.

Following is an analysis of the unwashed clay:

	Per cent.
Moisture	2.99
Ignition	14.80
Silica	43.31
Alumina	37.93
Ferric oxide	0.32
Lime	0.23
Magnesia	0.13
Potash	0.25
Soda	0.12
Titanic oxide	0.10
Sulphuric anhydride	A trace.
Total	100.18

The sample of which the analysis was made showed much iron stain. Some of the pieces were rather hard and greenish-white.

Commenting upon the samples analyzed from the Moss and Murray places, Dr. Peter says: "These ought to be fine porcelain clays, as they have nearly the same composition as kaolin. Possibly they might be used as fuller's earth, but this could only be determined by a practical test." He also noted that the white pieces are

perfectly infusible, even in the finest splinters, in the blow-pipe flame.*

A sample of this clay gave the following characteristics: Color, when mixed, yellowish-gray, both wet and dry; burned to cone 1 (2,102 degrees F.), the color was whitish-pink, becoming speckled, very light-gray at higher temperatures. Taste, lean and no grit. Texture, soft, and fine-grained. When disintegrated by prolonged shaking in water, no detritus remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 45.0 per cent of water, it made a fairly plastic paste, that shrank 6.0 per cent in drying and 19.0 per cent more in burning, giving a total shrinkage of 25.0 per cent. The air-dried mud showed a tensile strength of 44.7 pounds to the square inch, as the average of twelve tests, with a maximum strength of 53.2 pounds. There was no indication of vitrification at cone 9 (2,390 degrees F.).

The color of the mixture is not satisfactory and it has been proven that the deposit is of limited extent, having no commercial value.

CLAY No. 150. The Albert Hodges Place. Mr. Albert Hodges' farm is near the Munfordville and Priceville Road, about four miles northwest of Mundfordville, and two miles west of Dividing Ridge.

There is a clay exposure on this place at which the following section was taken:

1.	Soil and vegetation	3 ft.
2.	Yellow, plastic clay	2 ft.
3.	Dark clay	2 ft.
4.	Covered.	

The thickness of this dark clay below is not known, but it probably is three or four feet. A thorough examination could not be made on account of the exposure being along a spring branch where water interfered. The plastic clay is of good quality, so far as the body of the material is contained, but contains a considerable percentage of iron and magnesia, perhaps.†

*Ky. Geol. Surv., Bull. No. 6, p. 33-34.
†Ky. Geol. Surv., Bull. No. 6, p. 45.

A sample of this clay gave the following characteristics: Color, yellowish-green; burned to a dark red. Taste, fat, and very little grit. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that required slow drying, and that shrank 7.5 per cent in drying and a like amount additional when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 105 pounds to the square inch, as the average of six tests, with a maximum strength of 112 pounds. Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 6 (2,282 degrees F.). It burned to a hard, compact body and should make good conduit, tile, common brick, etc.

CLAY No. 144. The J. H. Priddy Place. Mr. J. H. Priddy lives about four miles west of Bonnieville on a neighborhood road connecting from Bonnieville with the Upton and Priceville Road.

A clay deposit is exposed here as a rim around the top of a high knob known as "Priddy's Knob." The clay is plastic near the top, but becomes lighter in color and more like kaolin towards the bottom.

The following is a section at a shaft on the side of the knob:

Conglomerate pebbles and soil	2 ft.
Drab clay, purer downwards	8 ft.
Brown stained kaolin	2½ ft.
Clay and oxide of managese	1½ ft.

This is quite an extensive deposit of clay and doubtless a valuable one. Although it is probable that this clay could not be washed to a sufficient degree of purity for the manufacture of fine china, yet it is of excellent quality for a low-grade pottery, tiling, etc.*

A sample of this clay gave the following charactertics: Color, when mixed, green; burned to a reddish-speckled-brown. Taste, fat, and somewhat gritty. When ground to 20-mesh and mixed with 35.0 per cent of water, it made an exceedingly plastic paste, that stood rapid drying, and that shrank 7.5 per cent in drying and an

*Ky. Geol. Surv., Bull. No. 6, p. 44.

additional 5.0 per cent in burning, giving a total shrinkage of 12.5 per cent. The air-dried mud showed a tensile strength of 60 pounds to the square inch, as the average of nine tests, with a maximum strength of 78 pounds. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 7 (3,318 degrees F.). This clay will make common brick, drain tile, etc., of a good quality.

CLAY No. 143. The James A. Hodges Place. One characteristic of the white clays of this section is that they break up into small angular pieces when exposed to the weather. These pieces are often found over the surface and mixed with the soil above a kaolin deposit, and are known as "outcroppings."

Nice outcroppings of kaolin are found on the farm of Mr. James A. Hodges, near the Bonnieville and Munfordville Road, two miles east of Bonnieville. On this farm there is a hollow two or three hundred yards long which shows these particles of clay around the inclosing hills. They occur in a belt, with a perpendicular thickness of about eight feet. No pits nor borings have been made into the deposit, but the indications are very flatteringly in favor of a nice deposit here.

The small pieces are of fine quality and very similar to the material found at other places in the field. The deposit is at the base of the Conglomerate Sandstone and here the following section was taken:

1.	Covered, Conglomerate pebbles and soil	
2.	Kaolin, "outcroppings"	8 ft.
3.	Covered	30 ft.
4.	Limestone, covered (St. Louis).	

An analysis of this clay (unwashed) is as follows:

	Per cent.
Moisture	3.77
Ignition (combined water and volatile matter)	15.76
Silica	37.86
Alumina	35.94
Ferric oxide	3.92
Lime	0.74
Magnesia	0.35
Potash	0.37

	Per cent
Soda	0.08
Phosphorus pentoxide	0.26
Sulphur trioxide and titanium dioxide	traces
Total	99.05

Dr. Peter makes the following comments on the analysis: "The proportion of iron is rather large in this clay. It could no doubt be used with more sandy material to produce terra cotta of very delicate shades."*

A sample of this clay gave the following characteristics: Color, when mixed, yellow; burned to a beautiful tint of pink to cone 7 (2,318 degrees F.), above which temperature it became a grayish-white. Taste, lean, and gritty. When ground to 20-mesh and mixed with 40.0 per cent of water, it made a lean paste, that shrank 5.0 per cent in drying and an additional 10.0 per cent when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 37 pounds to the square inch, as the average of eight tests, with a maximum strength of 46 pounds. There was no indication of vitrification at cone 11 (2,462 degrees F.). It burned to a sandy body. This is a refractory clay that would make a beautiful pink terra cotta or pressed brick.

CLAY No. 141. The C. E. Logsdon and E. T. Childers Places. These places are on the Cub Run and Priceville Road, about ten miles west of Dividing Ridge, Hart county, Ky.

A sample of this clay was labeled "yellow plastic clay, C. E. Logsdon; drab clay, E. T. Childers." Geological position as given by the collector was "Base of Big Clifty."

This sample gave the following characteristics: Color, when ground and mixed, green with slight yellowish tint; burned yellow at cone 1 (2,102 degrees F.), and brown at higher temperatures. Taste, fat, some grit. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.5 per cent in drying and a like amount

*Ky. Geol. Surv., Bull., No. 6, p. 35.

when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 68 pounds to the square inch, as the average of seven tests, with a maximum strength of 120 pounds. Complete vitrification occurred at cone 2 (2,138 degrees F.), with very little change at cone 6 (2,282 degrees F.). This is a common-brick and drain-tile clay.

CLAY No. 137. The George Knight Place. This place is four miles east of Bonnieville on a neighborhood road from Bonnieville to Frenchman's Knob.

The exposure here is on the side of a large hill. About two feet from the top of the deposit there issues a small spring, and the drab plastic clay is exposed two or three feet on down below the spring.

Small gullies around the same hill and adjacent hills show very similar exposures. The following is the section here:

1.	Soil and pebbles	4 ft.
2.	Drab, plastic clay	2 ft.
	Spring.	
3.	Drab, plastic clay	3 ft.
4.	Covered.	

Probably a valuable clay for drain tiles, water conduits, sewers, etc.*

A sample of this drab clay gave the following characteristics: Color, when mixed, yellowish-green; burned to dark red. Taste, fat, and gritty. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a mildly plastic paste, that shrank 10.0 per cent in drying and 3.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 81 pounds to the square inch, as the average of seven tests, with a maximum strength of 107 pounds. It burned to a hard, compact body, fully vitrified at cone 7 (2,318 degrees F.). Incipient vitrification occurred at cone 4 (2,210 degrees F.).

This is a good clay for the uses suggested above.

CLAY No. 136. The J. J. Hodges Place. A deposit of impure yellowish kaolin is found on this farm, but

*Ky. Geol. Surv., Bull., No. 6, p. 38.

is quite limited in quantity. This farm is on the Bonnieville and Cub Run Road, four miles southeast of Bonnieville. The deposit here is only about one foot thick and is exposed in a large gully which cuts through the Conglomerate down to the St. Louis. The following section was taken here on the side of a long ridge:

1.	Conglomerate sandstone	20 ft.
2.	Yellowish kaolin	1 ft.
3.	Covered (red sand)	10 ft.
4.	St. Louis limestone.	

The clay seems to be a good quality of kaolin and could possibly be washed white, but it is not in sufficient quantity to be of commercial interest.*

A sample of this clay gave the following characteristics: Color, pale yellow when mixed; burned to a pinkish-white up to cone 7 (2,318 degrees F.), becoming grayish-white at higher temperatures. When ground to 20-mesh and mixed with 44.0 per cent of water, it made a lean paste, that shrank 10.0 per cent in drying and 11.0 per cent more when vitrified, giving a total shrinkage of 21.0 per cent. The air-dried mud showed a tensile strength of 44 pounds to the square inch. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 11 (2,462 degrees F.). It burned to a hard, compact body that would make a beautiful pinkish-white pressed brick.

CLAY No. 135. The James Riggs Place. Mr. Riggs lives near the Bonnieville and Priceville Road, about three miles west of Bonnieville.

On this farm there is an exposure of plastic clay of good quality. Around a large hill east of his home, there are exposures of what seems to be an extensive deposit of clay. There is something like the following section here:

1.	Hill, covered with soil and sand.	
2.	Drab, plastic clay	14 ft.
3.	Covered	10 ft.
4.	St. Louis limestone	14 ft.

*Ky. Geol. Surv., Bull. No. 6, p. 42.

The clay possesses a fine body. It is very plastic and little mixed with foreign impurities. The color is a light drab and but for its plasticity might be taken for impure kaolin. This ought to be an excellent clay for the manufacture of tiling, conduits, flooring, etc., and possibly encaustic or vitrified wares.*

A sample of this clay gave the following characteristics: Color, when mixed, pale yellow; burned dark red. Taste, fat, some grit. When ground to 20-mesh and mixed with 32.5 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying and a like amount when vitrified, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 55 pounds to the square inch, as the average of five tests, with a maximum strength of 86 pounds. It was fully vitrified at cone 01 (2,066 degrees F.). This is a common-brick clay.

CLAY No. 131. The J. B. Hodges Place. Mr. Hodges' farm is on the Hammonsville and Bonnieville Road, one mile and a half east of Wabash. The main portion of the farm is low, with St. Louis Limestone exposures, but towards the south the land rises and breaks into hills capped with Conglomerate Sandstone.

On the hills to the south, there are exposures of a very fat clay of a drab color. The true thickness of the deposit is not determined, but the following is a section of the deposit at a cistern:

Conglomerate pebbles and soil	4 ft.
Drab, plastic clay	8 ft.
Covered	10 ft.
St. Louis limestone	6 ft.

In the days of early settlements in Hart County, this clay was mined for the purpose of manufacturing hand-made crocks and jars.†

A sample of this clay gave the following characteristics: Color, drab with some small yellow spots, drab when mixed; bright yellow when burned to cone 1 (2,102 degrees F.), becoming greenish-gray at cone 9 (2,390 degrees F.). Taste, fat, sour, very little grit. Texture, soft, fine-grained. When ground to 20-mesh and mixed

*Ky. Geol. Surv., Bull. No. 6, p. 41.
†Ibid. p. 39.

with 32.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 10.0 per cent in drying and 7.0 per cent more when vitrified, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strength of 86 pounds to the square inch, as the average of five tests, with a maximum strength of 102 pounds. Incipient vitrification occurred at cone 01 (2,066 degrees F.), with no appreciable change at cone 9 (2,390 degrees F.). It burned to a hard, compact body, free from warping. This is a good clay to go into a stoneware clay-mix. It needs more plasticity and greater toughness to permit its being turned on a potter's wheel.

CLAY No. 127. The J. Caswell Place. This place is on the Bonnieville and Hammonsville Road, about four and a half miles northeast of Bonnieville and a half mile east of Wabash.

There are several exposures here of a clay deposit. Gullies along a ridge expose the different layers at numerous places over an area of ten or fifteen acres, giving the following section:

1.	Soil	4 ft.
2.	Drab, plastic clay	3 ft.
3.	Pink, plastic clay	2½ ft.
4.	Dark, plastic clay	4 ft.
5.	Covered	15 ft.
6.	St. Louis limestone	6 ft.

These clay layers are very free from gritty or mineral impurities and are valuable clays for the manufacture of earthenware, etc. The dark layer at the bottom of the gullies is a plastic clay, but similar in appearance to the fire clays.

Following are analyses, made for the survey by Burk & Lynn:

Sample, a dark clay from farm of J. Caswell, on Bonnieville and Hammonsville Road, four and one-half miles east of Bonnieville, Hart County. No. 4 of the vertical section.

	Per cent.
Hygroscopic moisture	3.05
Combined water	7.69
Silica	56.73
Alumina	24.71

	Per cent.
Ferric oxide	3.72
Lime	0.38
Magnesia	0.15
Potash and soda	3.04
Titanium dioxide	0.79
Sulphur trioxide	0.84
Total	101.10

Analysis, ultimate and rational, of the pink plastic clay, No. 3 of the section, are as follows:

	Per cent.
Hygroscopic moisture	2.85
Combined water	6.98
Silica	60.52
Alumina	20.99
Ferric oxide	3.41
Lime	0.21
Magnesia	0.14
Potash and soda	2.85
Titanium dioxide	1.10
Sulphur trioxide	0.49
Total	99.52

The rational analysis gives:

	Per cent.
Clay substance	66.35
Quartz	30.64
Feldspathic detritus	3.01
Total	100.00(*)

A sample of this clay, labeled "Drab Clay and Fire Clay," gave the following characteristics: Color, drab; burned to a dark brown. Taste, fat, free from grit. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.5 per cent in drying and an additional 6.5 per cent when vitrified, giving a total shrinkage of 14.0 per cent. The air-dried mud showed a tensile

*Ky. Geol. Surv., Bull. No. 6, p. 39.

strength of 90 pounds to the square inch, as the average of three tests, with a maximum strength of 95 pounds. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 8 (2,354 degrees F.). The clay burned to a very hard, compact body, free from warping. This should make a high-grade stoneware.

CLAY No. 125. The James Logsdon Place. The exposure of clay on this farm is along the Munfordville and Cub Run Road, about four miles west of Munfordville.

There is a bold hill at this point which is capped with Conglomerate Sandstone. On the side of this hill, at the base of the above named formation, there are gullies exposing only partially a clay deposit. The thickness cannot be accurately determined, on account of soil covering, until a shaft or boring is made. The clay is of the plastic variety and has a pinkish drab color. On account of the covering, no definite section can be given at this deposit. Indications, however, favor a nice deposit of plastic clay at this place.*

A sample of this clay gave the following characteristics: Color, green, red and yellow; mixed, the color was yellow; burned dark red at cone 1 (2,102 degrees F.), changing to dark brown at higher temperatures. Taste, fat, very little grit. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.5 per cent in drying and an additional 10.0 per cent when vitrified, giving a total shrinkage of 17.5 per cent. The air-dried mud showed a tensile strength of 50 pounds to the square inch. Complete vitrification occurred at cone 2 (2,138 degrees F.), and partial viscosity at cone 5 (2,246 degrees F.). This clay would make an excellent common brick, drain tile, etc.

CLAY No. 124. The S. T. Isaacs Place. A deposit of plastic or pinkish-drab clay is exposed on the farm of Mr. S. T. Isaacs, near the Bonnieville and Munfordville Road, three miles southeast of Bonnieville.

In a shallow gully, the top of the bed is exposed only for a short distance. An opening was made with a spade to the depth of two feet, but the thickness of the deposit is not definitely known.

*Ky. Geol. Surv., Bull. No. 6, p. 46.

There is something like the following section here:

1.	Conglomerate pebbles and soil on hill.	
2.	Plastic clay, exposed	25 ft.
3.	Covered	25 ft.
4.	St. Louis limestone	3 ft.

This is a good quality of plastic clay doubtless for tiling, earthenware, brick, etc. Near the surface the clay is somewhat gritty, but this is likely due to the sand having been washed into it from above by rains.*

A sample of this clay gave the following characteristics: Color, pinkish-drab; burned to a yellowish-red at cone 1 (2,102 degrees F.), and then to dark brown at higher temperatures. Taste, fat, sour, somewhat gritty. Texture, soft, fine-grained, massive and uniform. When ground to 20-mesh and mixed with 24.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 10.0 per cent in drying and 7.5 per cent more when vitrified, giving a total shrinkage of 17.5 per cent. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 7 (2,318 degrees F.). This is a good clay for earthenware, etc.

CLAY No. 123. The W. G. W. Butler Place. Mr. Butler's farm is about two and a half miles southwest of Upton, on the Upton and Priceville Road. The Big Clifty Sandstone occurs here in regular position above the St. Louis Limestone. Along a drain which cuts across the exposure, we find two similar deposits exposed. One near the top or just above the Big Clifty, the other at the base next to the St. Louis Limestone. The following is a section including both deposits of plastic clay:

1.	Layers of Chester sandstone	20 ft.
2.	Drab, plastic clay	10 ft.
3.	White, sandy shale	2 ft.
4.	Big Clifty sandstone	75 ft.
5.	Drab, plastic clay	10 ft.
6.	White, sandy shale	2 ft.
7.	St. Louis limestone	6 ft.

*Ibid., p. 37.

The clays of these two deposits are very similar. Both are underlaid by similar white, siliceous shale. There are no signs of faulting, however; this similarity is merely a coincidence.

The clay is of excellent quality and very free from physical impurities. Following is an analysis of the crude clay, from the upper bed, No. 2:

	Per cent.
Moisture	3.04
Ignition (combined water and volatile matter)	6.05
Silica	61.90
Alumina	19.17
Ferric oxide	3.69
Lime	0.54
Magnesia	1.20
Potash	2.93
Soda	0.11
Phosphorus pentoxide	0.08
Titanium dioxide	1.14
Sulphur trioxide	tr.
Total	99.85

Commenting on the analysis, Dr. Peter says: "This clay should be excellent for making building brick, tiles, etc., or for Portland Cement."*

A sample of this clay gave the following characteristics: Color, green; burned to a dark red. Taste, fat, slightly gritty. When ground to 20-mesh and mixed with 26.0 per cent of water, it made a plastic paste, that shrank 9.0 per cent in drying and 6.0 per cent additional when vitrified, giving a total shrinkage of 15.0 per cent. Complete vitrification occurred at cone 03 (1,994 degrees F.), partial viscosity at cone 6 (2,282 degrees F.). This is a common-brick clay.

CLAY No. 75. The J. S. Priddy Place. This farm is on the Upton and Priceville Road about three miles southwest of Upton.

The following is the section at an exposure of drab, plastic clay on Mr. Priddy's place:

*Ky. Geol. Surv., Bull. No. 6, p. 43.

1.	Covered	5 ft.
2.	Drab, plastic clay	3 ft. 8 in.
3.	Covered ..	30 ft.
4.	St. Louis limestone.	

This clay is a very similar material to that found at numerous places in this territory. At the top the deposit is colored red by iron oxide which has leached in from above. Towards the bottom, the deposit is covered with soil and vegetation to such an extent that the entire thickness was not accurately determined. The amount of impurities present is probably not large enough to injure the clay in the manufacture of tiles, sewers, etc.*

A sample of this clay gave the following characteristics: Color, red, gray and yellow; when mixed, reddish-yellow; burned to a very dark red. Taste, fat, sour, and quite gritty. Texture, rather soft, coarse-grained, compact. When ground to 20-mesh and mixed with 37.5 per cent of water, it made a very plastic paste, that required slow drying, and that shrank 10.0 per cent in drying and an additional 5.0 per cent when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 83 pounds to the square inch, as the average of seven tests, with a maximum strength of 111 pounds. It burned to a hard, compact body. Incipient vitrification occurred at cone 02 (2,030 degrees F.), complete at cone 6 (2,282 degrees F.). This clay should make a good grade of paving brick.

CLAY No. 72. The S. S. Hodges Place. This farm is near the Hammonsville and Munfordville Road, about five miles northeast of Munfordville.

In a field west of Mr. Hodges' home, there is a low depressed hill surrounded by higher ones. This hill and the ones around show exposures of St. Louis Limestone from base to summit. Around the top of the central high land there are signs of kaolin.

We get the following section here:

1.	Covered (chert and soil on hill).	
2.	Layer of iron carbonate	4 ft.
3.	Laminated sand and kaolin	3½ ft.
4.	Space, with small outcroppings of kaolin	10 ft.
5.	St. Louis limestone	6 ft.

*Ky. Geol. Surv., Bull. No. 6, p. 43.

No definite deposit has been located here, and it is very probable that the particles are only the remainder, or inheritance so to speak, of a deposit that once existed here at the top of the St. Louis.*

A sample of this "sand, chert and kaolin outcroppings" gave the following characteristics: Color, yellow and white; mixed, yellow with white specks; it burned dark red with white specks. Taste, lean and gritty. Texture, variable, but, in general, hard and coarse-grained. When ground to 30-mesh and mixed with 24.0 per cent of water, it made a mildly plastic paste, that stood a fair rate of drying, and that shrank 5.0 per cent in drying and almost none in burning. The air-dried mud showed a tensile strength of 45.7 pounds to the square inch, as the average of seven tests, with a maximum strength of 52.6 pounds. Incipient vitrification occurred at cone 7 (2,318 degrees F.), and not complete at cone 11 (2,462 degrees F.). It cracked rather badly in burning, which would be against its value. It is a refractory, red-burning clay.

CLAY No. 71. The Elizabeth Wilson Place. Mr. Wilson's farm is on the Bonnieville and Cub Run Road, three miles southwest of Bonnieville.

On this place there are very marked exposures of a clay deposit, as shown in several gullies cutting across a ridge.

The following section was taken here:

1.	Sandstone	30 ft.
2.	Brown, plastic clay	6 ft.
3.	Covered.	

This clay contains a considerable percentage of iron and manganese, and will doubtless burn red, in which case it might be valuable as a brick clay or low-grade earthenware.†

A sample of this clay gave the following characteristics: Color, red to brown, with some green pieces; mixed, grayish brown; burned to a dark red. Taste, lean and gritty. Texture, hard, coarse-grained. When ground to 30-mesh and mixed with 16.0 per cent of water, it made a rather lean paste, that stood rapid drying,

*Ky. Geol. Surv., Bull. No. 6, p. 45.
†Ky. Geol. Surv., Bull. No. 6, p. 42.

and that shrank 5.0 per cent in drying and very little more when vitrified. The air-dried mud showed a tensile strength of 69 pounds to the square inch, as the average of eight tests, with a maximum strength of 84 pounds. This clay burned without warping when in thin slabs, and was fully vitrified at cone 3 (2,174 degrees F.). This is a low-grade clay that may be used for making drain tile or common brick.

CLAY NO. 51. The G. R. Thorpe Place. This farm is on the Hammonsville and Munfordville Road, about three and a half miles northeast of Bonnieville and one mile southeast of Wabash. Two deep intersecting gullies expose three different layers of clay in a deposit here.

At the exposure the following section is exposed:

1.	Soil and Conglomerate sand	20 ft.
2.	Yellow, plastic clay	1½ ft.
3.	Pink, plastic clay	1 ft.
4.	Drab, plastic clay	3 ft.
5.	Covered.	

The clay shows at other points on surrounding hills at the same elevation. This plastic clay is similar to other plastic clays in this locality and valuable for the same purposes.*

A sample of this yellow, pink and drab clay gave the following characteristics: Color, pink, yellow and drab; mixed, yellowish-drab; it burned to a yellowish-drab and then to a gun-metal color. Taste, fat and gritty. Texture, irregular. When ground to 30-mesh and mixed with 26.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and 5.0 per cent more in burning, giving a total shrinkage of 12.0 per cent. The air-dried mud showed a tensile strength of 132 pounds to the square inch, as the average of six tests, with a maximum strength of 177.4 pounds. The clay burned to a hard, compact body, completely vitrified at cone 9 (2,390 degrees F.). Warping occurred when thin plates were burned, but not to such an extent as to prohibit its use as a terra cotta. This clay is tough enough and has the proper plasticity to permit its being turned on a potter's wheel, and pos-

*Ibid., p. 39.

sesses sufficient refractoriness to make the ware hold its shape in burning. This clay has the proper qualities to recommend its use in mixtures for the manufacture of stoneware.

CLAY No. 42. The Samuel Goldsmith Place. This farm is one mile east of Dividing Ridge, on a country road to Munfordville.

There is a clay exposed here of the plastic variety which has a pinkish-drab color with yellow spots due to iron. This deposit is in the form of a sharp anticlinal fold. A pit has been sunk into the deposit on each side of the axis only ten feet apart. Above the clay there is eight feet of sand colored bright red with iron oxide. It is from this sand that iron has leached into the clay below, giving it a spangled appearance. Below the deposit there is an exposure of St. Louis Limestone. The following is the section at this exposure:

1.	Soil	1 ft.
2.	Red sand (conglomerate)	8 ft.
3.	Pinkish drab clay	5 ft.
4.	Covered	15 ft.
5.	St. Louis limestone.	

This clay is free from grit and would probably burn to a nice tile regardless of the iron which it contains.*

A sample of this clay gave the following characteristics: Color, pinkish-drab with yellow; mixed, the color was dark drab; remained dark drab when burned. Taste, fat, sour and free from grit. Texture, soft, fine-grained, banded. When ground to 16-mesh and mixed with 35.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and 7.0 per cent additional when vitrified, giving a total shrinkage of 15.0 per cent. The tensile strength of the air-dried mud, as shown by the average of four tests, was 70.6 pounds to the square inch, with a maximum strength of 87 pounds. The clay burned to a hard, compact body, and was fully vitrified at cone 6 (2282 degrees F.). It warped somewhat in burning. This is a good grade of clay and would answer for a sewer pipe clay.

*Ky. Geol. Surv., Bull. No. 6, p. 37.

CLAY No. 35. The John Wilkerson Place. The following is the analysis of a hard clay of bluish-gray color from the farm of Mr. John Wilkerson on the Munfordville and Leitchfield Road, (about four miles west of Munfordville and two miles west of Dividing Ridge Station.) The clay is of unknown thickness, but very thick. There is probably something like forty feet of this hard, shaly clay. A deep pit was once dug into this deposit, but was not accessible at the time of examination.

	Per cent
Hygroscopic moisture	3.34
Combined water	5.24
Silica	64.68
Alumina	17.35
Ferric oxide	3.29
Lime	0.26
Magnesia	1.09
Potash and soda	3.74
Titanium dioxide	1.06
Sulphur trioxide	0.28
Total	100.33(*)

A sample of this clay gave the following characteristics: Color when dry, yellowish-brown; when wet, brown; burned to cone 1 (2102 degrees F.), the color was reddish-brown and full of white specks, becoming dark brown at higher temperatures. Taste, fat and gritty. No detritus remained on the 100-mesh sieve after distintegration by prolonged shaking in water. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a fat paste, that shrank 9.0 per cent in drying and 8.0 per cent additional when vitrified, giving a total shrinkage of 17.0 per cent. The tensile strength of the air-dried mud was 128 pounds to the square inch, as shown by the average of three tests, with a maximum strength of 137.7 pounds. Incipient vitrification occurred at cone 1 (2,102 F.), complete at cone 6 (2,282 degrees F.).

This clay is suited to the manufacture of drain tile and paving brick.

*Ky. Geol. Surv., Bull. No. 6, p. 48.

CLAY No. 149. This represents another sample from the John Wilkerson farm and labeled, "Shaft sixty feet deep; lower four feet clay."

This sample gave the following characteristics: Color, pale yellow; burned to a pale-red to yellowish-red. containing white specks at cone 1 (2,102 degrees F.), and to a brownish-gray, with white specks remaining, at higher temperatures. Taste, fat, and gritty. When ground to 30-mesh and mixed with 30.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and 8.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 15.0 per cent. Incipient vitrification occurred at cone 9 (2,390 degrees F.), not complete at cone 11 (2,462 degrees F.).

This is an impure, low-grade kaolin that would make a fair grade of pressed brick.

CLAY No. 31. The William Priddy Place. Mr. William Priddy lives in Hart county on the Upton and Priceville Road, about six miles west of Upton. A pit has here been dug into the clay, but no definite deposit has been located. The material occurs in irregular layers at the top of the St. Louis. The following is the section here:

1.	Conglomerate pebbles and sand	20 ft.
2.	Plastic clay and yellow soil	5 ft.
3.	St. Louis limestone	6 ft.

The clay is of a drab, plastic color and contains a great quantity of gypsum crystals. The crystals set thickly through the layers, giving a granular and glistening appearance. On two or three of the immediate hills at the same elevation, we get similar exposures of the same deposit.*

A sample of this clay gave the following characteristics: Color, drab and yellow, showing crystals of gypsum; when mixed, the color was yellow, both wet and dry; burned to cone 1 (2,102 degrees F.), the color was reddish-brown, becoming dark brown at higher temperatures. Taste, fat, sour, and gritty. Texture, soft, crumbly and coarse-grained. When disintegrated by prolonged shaking in water, much gypsum and limonite was

*Ky. Geol. Surv., Bull. No. 6, p. 42.

caught on the 100-mesh sieve. When ground to 20-mesh and mixed with 20.0 per cent of water, it made a plastic paste, that required slow drying, and that shrank 7.0 per cent in drying and 2.0 per cent more when burned to cone 1 (2,102 degrees F.), giving a total shrinkage of 9.0 per cent. The air-dried mud showed a tensile strength of 172 pounds to the square inch, as the average of four tests, with a maximum strength of 236.5 pounds. At cone 1 (2,102 degrees F.) the clay was nearly vitrified and showed white particles and was full of small holes; at cone 6 (2,282 degrees F.), it was partially fused. This is a very low-grade clay.

CLAY NO. 23. The J. L. Arterbury Place. This place is on the Upton and Priceville Road, three miles southwest of Upton.

There is a deposit of drab, plastic clay here between the St. Louis Limestone and the Big Clifty Sandstone. The clay is exposed at several points along a long ridge. At a pit sunk at one place the following section was taken:

1.	Sand and soil	3	ft.
2.	Drab, plastic clay	3½	ft.
3.	Shale	4	in.
4.	Drab, plastic clay	1	ft.
5.	Shale at bottom of pit	4	in.
6.	Covered	20	ft.
7.	St. Louis limestone	10	ft.

This is a very impure variety of plastic clay, being mixed to a large extent with iron and manganese oxide.*

A sample of this clay gave the following characteristics: Color, drab and yellow; ground and mixed, yellowish-brown; burned to cone 1 (2,102 degrees F.), it became dark red, changing to dark brown at higher temperatures.

Taste, lean and very gritty. Texture, coarse-grained, containing roots and fibers. When disintegrated by prolonged shaking in water, the only detritus caught on the 100-mesh sieve was roots and fibers. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a moderatly plastic paste, that required slow dry-

*Ky. Geol. Surv., Bull. No. 6, p. 43.

ing, and that shrank 8.3 per cent in drying. Incipient vitrification occurred at cone 1 (2,102 degrees F.), and fusion at cone 5 (2,246 degrees F.). This clay cracks too much in burning to be of any commercial value, even for common brick.

CLAY NO. 19. The Stamp-Clark Exposures. These exposures are just outside the town of Bonnieville, to the west on either side of the Bonnieville and Priceville Road. There are exposures of a deposit here which is more interesting from a geological point of view than from a commercial one.

The exposures are in the plane of a normal fault. The St. Louis Limestone and Chester Sandstones are turned on edge and a displacement occurs of about one hundred feet. This clay deposit was formed before the disturbance took place and is faulted in a similar way as are the strata. The fault plane or strike runs in a northeast southwest direction, dipping southeast. On the west side, next to the St. Louis Limestone, there is a deposit of plastic clay turned on edge, with a thickness of two feet This deposit is exposed to the north of Mr. J. M. Stamp and to the south of Dr. J. H. Clark. The clay is a very impure variety of drab, plastic clay, and is neither in sufficient quantity nor in favorable position to be profitably mined. The deposit is evidently very old and certainly of sedimentary origin.*

A sample of this clay gave the following characteristics: Color, pale yellow, both wet and dry; burned to cone 1 (2,102 degrees F.), the color was bright yellow, mottled with red specks; at cone 6 (2,282 degrees F.), the yellow remained only as a tint, while at higher temperatures the color was muddy-gray, with dark specks throughout. Taste, fat, and very little grit. When disintegrated by prolonged shaking in water, considerable limonite detritus was caught on the 100-mesh sieve. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 7.0 per cent more when vitrified, giving a total shrinkage of 12.0 per cent. The tensile strength of the air-dried mud was 114.2 pounds to the square inch, as the average of ten tests, with a maximum strength of 126.3 pounds. In-

*Ky. Geol. Surv., Bull. No. 6, p. 41.

cipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 9 (2,390 degrees F.).

CLAY NO. 17. Pink and drab clay from the Jesse Craddock Place, on the Cub Run and Priceville Road, two miles from Cub Run, Hart county. Geological position, base of Big Clifty.

A sample of this clay gave the following characteristics: Color, pink and drab; when ground and mixed the color was pinkish-drab, somewhat mottled with dark grains when dry; brown when wet; burned to cone 1 (2,102 degrees F.), the color was red, becoming very dark red to brown at higher temperatures. Taste, fat, and gritty. Texture, a mixture of slate-like pieces mingled with clay; contained roots and fibers. After disintegration by prolonged shaking in water, a considerable quantity of detritus consisting of slate and gravel, remained on the 100-mesh sieve. When ground to 20-mesh and mixed with 22.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and a like amount when vitrified, giving a total shrinkage of 14.0 per cent. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 7 (2,318 degrees F.).

The air-dried mud showed a tensile strength of 150.5 pounds to the square inch, as the average of six tests, with a maximum strength of 188 pounds. This is a common-brick and drain-tile clay.

CLAY NO. 147. The J. B. Isaacs Place. This place is on the Bonnieville and Munfordville Road, four miles southeast of Bonnieville. On the above named farm there is a small spring which issues from between layers of plastic clay. This clay is of a grey color with small red specks.

There is an exposure of two and a half feet above this spring. This layer contains a considerable amount of organic matter and iron, while below the spring the clay is of purer quality and shows an exposure of ten feet. Here the following section is exposed:

1. Soil and pebbles	8	ft.
2. Speckled plastic clay	2½	ft.
Spring.		
3. Drab, plastic clay	10	ft.
4. Covered	20	ft.
5. St. Louis limestone	3	ft.

This clay is free from grit, quite porous, and likely a valuable material for tiling or fire brick. Following is an analysis of the clay made for the Survey by Burk & Lyon, Louisville, Ky.:

Sample, a reddish brown, or drab speckled, plastic clay, from the farm of J. B. Isaacs, on Bonnieville road, four miles southeast of Bonnieville.

	Per cent.
Hygroscopic moisture	4.62
Combined water	6.86
Silica	54.07
Alumina	22.60
Ferric oxide	5.04
Lime	0.28
Magnesia	0.50
Potash and soda	4.61
Titanium dioxide	0.93
Sulphur trioxide	0.27
Total	99.78

A rational analysis of the foregoing shows the following:

Clay substance	84.58
Quartz	14.14
Feldspathic detritus	1.28
Total	100.00(*)

A sample of this clay gave the following characteristics: Color, purplish to brown; burned yellowish-red at cone 1 (2,102 degrees F.), becoming light to bluish-brown when viscous. Taste, fat, very little grit. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a very plastic paste, that shrank 10.0 per cent in drying and an additional 3.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 45 pounds to the square inch, as the average of seven tests, with a maximum strength of 67 pounds. Complete vitrification occurred at cone 2 (2,138 degrees F.). This is a fair-grade of common-brick or drain-tile clay.

*Ky. Geol. Surv., Bull. No. 6, p. 29.

HARDIN COUNTY.

CLAY NO. 37. The H. W. Rahm Place. The clay exposures on this place are typical of the clayey subsoil near Stithton.

Mr. Rahm's farm is about one mile north of Stithton, and lies just west of the I. C. R. R. This is a low, level territory underlaid by a light colored clay about five feet in thickness, which has been exposed on this farm by deep postholes, excavation of pond, etc. The section exposed at this point follows:

1.	Soil	2½ ft.
2.	Light colored clay	3 ft.
3.	St. Louis limestone.	

The soil grades gradually into the silicious material below, but is at places much thicker than at others.

Following is the analysis made for the Survey by Burk & Lyon, Louisville, Ky.:

Sample, light gray clay, from farm of H. W. Rahm, one mile north of Stithton.

	Per cent.
Hygroscopic moisture	1.80
Combined water	4.69
Silica	77.33
Alumina	9.37
Ferric oxide	3.11
Lime	1.10
Magnesia	0.02
Potash and soda	2.12
Titanium dioxide	1.11
Sulphur trioxide	0.48
Total	101.13(*)

A sample of this clay labeled, "One-half mile north and three hundred yards west of the I. C. R. R., in an orchard at a pond, on the farm of H. W. Rahm," gave the following characteristics: Color, drab; when burned to cone 1 (2,102 degrees F.), it became a bright yellow, changing to reddish-yellow at higher temperatures, and finally to a yellowish-brown. Taste, lean, slightly sour,

*Ky. Geol. Surv., Bull. No. 6, p. 22.

and some grit. Texture, soft, fine-grained and massive. When disintegrated by prolonged shaking in water, a little sandy detritus remained on the 100-mesh sieve. When ground to 20-mesh and mixed with 27.0 per cent of water, it made a fairly plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and 3.0 per cent more in burning, giving a total shrinkage of 10.0 per cent. The tensile strength of the air-dried mud was 145 pounds to the square inch. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 7 (2,318 degrees F.).

This clay will make good common brick, drain tile and a fair grade of red pressed brick. It would make a stoneware of the lower grade, such as is manufactured by some of the small potteries.

CLAY No. 152. Another sample of clay from the farm of H. W. Rahm, was collected from a sink-hole in a meadow, one hundred yards west of the I. C. R. R., and gave the following: Color, yellow; burned dark red, speckled with white. Taste, fairly fat, and very gritty. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a pairly plastic paste, that shrank 7.0 per cent in drying and 3.0 per cent additional when vitrified, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 142 pounds to the square inch, as the average of six tests, with a maximum strength of 156 pounds. It burned to a hard, compact body. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 7 (2,318 degrees F.). The white specks were not vitrified. This is the same grade of clay described above under Clay No. 37. It would make a fair grade of paving brick.

CLAY No. 33. The Harrison Ashlock Place. Mr. Ashlock's farm is on the East View and Meeting Creek Road, about two miles west of East View.

The deposit is of limited extent, but interesting because of its geological location. It is not found in the base of the Big Clifty, as are most of the deposits in this section. but is higher up in the series. The following section was taken at this point:

1.	Thin layer of sandstone	10	ft.
2.	Bluish, plastic clay	2½	ft.
3.	Stratum of limestone	40	ft.
4.	Big Clifty sandstone	40	ft.

This deposit is of too limited thickness and horizontal extent to be of much commercial interest. It occurs at the same geological horizon as do many of the plastic clays of Grayson county, namely, above a limestone at the top of the Big Clifty Sandstone.*

A sample of this clay gave the following characteristics: Color, gray and yellow; when mixed, yellowish-gray, both wet and dry; burned to cone 1 (2,102 degrees F.), the color was dark red, turning to dark brown at higher temperatures. Taste, lean and very gritty. Texture, soft, coarse-grained and very irregular. No detritus was caught on the 100-mesh sieve after disintegration by prolonged shaking in water. When ground to 20-mesh and mixed with 20.0 per cent of water, it made a mildly plastic paste, that stood a moderate rate of drying, and that shrank 7.0 per cent in drying and 6.0 per cent more when burned to cone 1 (2,102 degrees F.), giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 107.5 pounds to the square inch, as shown by the average of five tests, with a maximum strength of 129 pounds. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 7 (2,318 degrees F.). This clay will make common brick and drain tile.

CLAY NO. 29. The Chas. Carby Place. This sample is a hard shale from Mr. Chas. Carby's place on the White Mills and Millerstown Road, one-half mile north of Millerstown, Hardin county, Ky. Geological position, St. Louis.

A sample of this shale gave the following characteristics: Color, when dry, dark gray with some yellow; when wet, dark, greenish-gray; when burned to cone 1 (2,102 degrees F.), the color was bright red, turning to dark brown at higher temperatures. Taste, lean. When ground to 20-mesh and mixed with 25.0 per cent of water it made a fair paste, that required great care in drying, and that shrank 7.0 per cent in drying and 3.0 per cent more in burning, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 63.4 pounds to the square inch, as the average of ten tests, with a maximum strength of 87.2 pounds. The shale is fine-grained. It was fully vitrified at cone 1 (2,102

*Ky. Geol. Surv., Bull. No. 6, p. 26.

degrees F.), and fused at cone 9 (2,390 degrees F.). This is a worthless shale.

CLAY NO. 138. The S. H. Richardson Place. This farm is on the Elizabethtown and Meeting Creek Road, about three miles and a half northwest of East View.

This land is at a high elevation, with Big Clifty Sandstone as the surface rock. One deep hollow extends down to the St. Louis Limestone, and here there is a deposit of yellow plastic clay with an exposure of four feet. It is a good quality of yellow clay and might be used for terra cotta. It is free from mineral impurities and is quite plastic when wet. At this place we get the following section:

1.	Big Clifty sandstone	80 ft.
2.	Yellow plastic clay	4 ft.
3.	St. Louis limestone	15 ft.

This deposit is very inconvenient, being exposed in a deep hollow. Considerable expense would be necessary before the material could be gotten to a place of easy transport. The construction of an incline would perhaps simplify the proposition.*

A sample of this clay gave the following characteristics: Color, yellow; burned dark red. Taste, fat, and gritty. When ground to 20-mesh and mixed with 32.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and 6.0 per cent more when vitrified, giving a total shrinkage of 14.0 per cent. The air-dried mud showed a tensile strength of 70 pounds to the square inch, as the average of four tests, with a maximum strength of 100 pounds. The material puffed up badly at cone 01 (2,066 degrees F.), and is a very low grade, common-brick clay.

CLAY NO. 133. The J. D. Barnes Place. Mr. Barnes' farm is on the Elizabethtown and Meeting Creek Road, two miles and a half west of East View.

At a spring three-quarters of a mile south of the above mentioned road, the following section was taken:

1.	Shaly limestone	4 ft.
2.	Fire clay	3 ft.
3.	Coal ..	1 ft.
4.	Fire clay	3 ft.
5.	Covered.	

*Ky. Geol. Surv., Bull. No. 6, p. 24.

The thin stratum of coal is no indication that coal occurs thereabouts in paying quantities, but is interesting from a geological standpoint. The St. Louis Limestone is not exposed here, but from barometric readings is not many feet beneath the surface.

The "fire clay" contains too great a quantity of impurities to be valuable for refractory qualities. It is not a fire clay in the true sense of the term. Perhaps it should be called a soft, shaly clay resembling fire clay.

A sample of this "fire clay," or "soft shaly clay resembling fire clay," gave the following characteristics: Color, greenish-gray; burned yellow, and then brown. Taste, lean, and some grit. When ground to 20-mesh and mixed with 22.0 per cent of water, it made a moderately plastic paste, that shrank 5.0 per cent in drying and a like amount when burned to cone 1 (2,102 degrees F.), giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 71.5 pounds to the square inch, as the average of three tests, with a maximum strength of 76 pounds. The clay burned to a yellow shell with black pumice-like interior at low temperatures and is of little or no commercial value.

CLAY No. 132. The J. B. Jenkins Place. This farm is about one and a quarter miles south of Stephensburg, on the I. C. R. R.

The clay exposures here are around a high ridge at the southern part of the farm, and a section of the exposures here shows the following:

1.	Big Clifty sandstone.	
2.	Yellow plastic clay	2 ft.
3.	Drab plastic clay	14 ft.
4.	Oolitic limestone	20 ft.

The yellow clay is very plastic, fairly smooth, and contains a large percentage of iron. The drab plastic clay is fine-grained, homogeneous and large enough in quantity to be easily mined.

This is seemingly a valuable clay for the manufacture of tiling, sewer pipe, etc., and possibly would make a real nice brick.*

* Ky. Geol. Surv., Bull. No. 6, p. 22.

A sample of this clay gave the following characteristics: Color, when mixed, yellow; burned to a dark red. Taste, lean and gritty. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a fairly plastic paste, that shrank 5.0 per cent in drying and 7.5 per cent when vitrified, giving a total shrinkage of 12.5 per cent. The air-dried mud showed a tensile strength of 90 pounds to the square inch, with a maximum strength of 126 pounds. Incipient vitrification occurred at cone 5 (2,246 degrees F.), complete at cone 9 (2,390 degrees F.). It burned to a rather porous body. This clay will make an excellent grade of brick and tile.

CLAY NO. 128. The West Point Clays. At places in the bottom of the Ohio River around West Point, noticeably on the farm of Mr. William T. Turner, just west of the town, the soil is underlaid by a light colored plastic clay with a thickness of five or six feet. The color varies at different points.

The low meadow lands east of the mouth of Salt River, in Jefferson county, have a similar subsoil, but with less impurities. It is this material which is used in the manufacture of Portland Cement at River View, Jefferson county, Ky., by the Kosmos Portland Cement Company.

Following is the analysis of this clay as furnished by the superintendent, Mr. Wm. H. Baker, made by B. Cushman, of Cornell University:

	Per cent.
Alumina	20.02
Silica	63.45
Ferric oxide	4.63
Lime	0.47
Magnesia	0.98

The oolitic limestone which is ground and mixed with this material has the following composition:

	Per Cent.
Calcium carbonate	98.49
Magnesium carbonate	0.42
Silica	0.37
Alumina	0.12
Ferric oxide	0.11†

†Ibid. p. 21.

A sample of this clay, from the farm of Mr. Turner, one-fourth mile south of the Ohio River, and one mile west of West Point gave the following characteristics: Color, dark gray; burned to yellow at cone 1 (2,102 degrees F.), changing to dark red at higher temperatures. Taste, fat, very little grit. When ground to 20-mesh and mixed with 23.0 per cent of water, it made a fat paste, that stood rapid drying, and that shrank 6.0 per cent in drying and an additional 7.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The sample was too small to make a tensile strength test. Incipient vitrification occurred at cone 3 (2,174 degrees F.), complete at cone 7 (2,318 degrees F.). It burned to a hard, compact body that would do for paving brick, etc.

CLAY No. 129. Illinois Central Railroad Deposit. There is a deposit of drab plastic clay exposed in the I. C. R. R. cut, about two hundred yards south of the station at East View. This is a short cut across a ridge which runs at right angles to the railroad and extends back into high lands on either side. The deposit is twelve feet thick. At this cut the following section is exposed:

1.	Big Clifty sandstone	15 ft.
2.	Drab plastic clay	12 ft.
3.	Blue, coarse-grained St. Louis limestone	8 ft.
4.	Oolitic limestone (St. Louis)	10 ft.

Several years ago a number of tons of this clay were shipped to Bannon & Co., Louisville, for the purpose of making piping. The clay was reported too fusible, however, and the mining was discontinued.

By the mixing of a small percentage of silica, this material would be rendered more refractory and could probably be used profitably and with good results.*

A sample of this clay gave the following results: Color, drab and yellow; pale yellow when ground and mixed; burned to a dark brown. Taste, fat, some grit. Texture, shaly, soft, fine-grained. When ground to 20-mesh and mixed with 32.0 per cent of water, it made a plastic paste, that stood a fair rate of drying, and that shrank 10.0 per cent in drying and an additional 7.5 per

*Ky. Geol. Surv., Bull. No. 6, p. 25.

cent when vitrified, giving a total shrinkage of 17.5 per cent. The air-dried mud showed a tensile strength of 98 pounds to the square inch, as the average of eight tests, with a maximum strength of 133 pounds. Incipient vitrification occurred at cone 2 (2,138 degree F.), complete at cone 7 (2,318 degrees F.). It burned to a good body and is a fair grade of sewer-pipe or paving-brick clay.

CLAY No. 130. The Wash Nicholls Place. The farm of Mr. Wash Nicholls is on the East View and Meeting Creek Road, two miles west of East View.

Alongside the above-mentioned road there is quite an extensive and varied clay exposure, as shown by the following section:

1.	Big Clifty sandstone	5	ft.
2.	Bluish marl	6	in.
3.	Drab plastic clay	10	ft.
4.	Dark, red and drab clay	5	ft.
5.	Dark alone	2½	ft.
6.	Red and dark	3	ft.
7.	Bluish marl	10	in.
8.	Covered	15	ft.
9.	St. Louis limestone	2	ft.

The drab plastic layer at the top is a valuable clay for agricultural structures, sewers, etc. The red is very ochreous and might be valuable for the manufacture of paint if separated from the dark and drab. The dark clay is plastic and would likely burn to a similar colored material as the drab plastic layer at the top. It is also probable that a mixture of the whole deposit could be profitably worked, provided the marls do not furnish an excess of lime.*

A sample of this clay, labeled "fire clay, drab and red," gave the following characteristics: Color, when mixed, brownish-gray; burned to dark red. Taste, lean, not much grit. When ground to 20-mesh and mixed with 22.0 per cent of water, it made a paste rather low in plasticity, that required slow drying, and that shrank 6.0 per cent in drying and a like amount additional when vitrified, giving a total shrinkage of 12.0 per cent. The clay was fully vitrified at cone 01 (2,066 degrees F.), and

*Ky. Geol. Surv., Bull. No. 6, p. 25.

somewhat viscous at cone 6 (2,282 degrees F.). This is a low-grade, common-brick clay.

CLAY No. 74. The William Deaver Place. This farm is in what is known as Deaver's Hollow, on the Summit and Meeting Creek Road, three miles west of Summit. The picturesque little place is surrounded by high cliffs of Big Clifty Sandstone, while St. Louis Limestone is only a few feet beneath the surface. On the east side of his farm there is a low hill, which rises gradually to the cliffs of sandstone and includes a semi-circular area of about five acres. This area is underlaid by a deposit of drab, plastic clay with an exposure of about four feet. The following section is exposed at this point:

1.	Big Clifty sandstone	90 ft.
2.	Drab, plastic clay	4 ft.
3.	Covered	10 ft.
4.	St. Louis limestone	3 ft.

The clay is mixed with earthy impurities at the exposure, but would show to much better advantage if exposed by a shaft, and probably prove valuable.*

A sample of this clay gave the following characteristics: Color, yellow to brown; mixed, yellowish-brown; burned to a very dark red. Taste, slightly fat and very gritty. Texture, soft, coarse-grained, massive. When ground to 20-mesh and mixed with 26.0 per cent of water, it made a fairly plastic paste, that required great care in drying, and that shrank 10.0 per cent in drying and 7.5 per cent additional when vitrified, giving a total shrinkage of 17.5 per cent. The air-dried mud showed a tensile strength of 134 pounds to the square inch, as the average of four tests, with a maximum strength of 245 pounds. It burned to a hard, compact body, fully vitrified at cone 8 (2,354 degrees F.). Incipient vitrification occurred at cone 2 (2,138 degrees F.).

This is a good paving-brick or stoneware clay.

CLAY No. 139. This clay, labeled "Wm. Deaver, Summit, Hardin county, Ky.," differs in color from Clay No. 74, which has just been described.

This sample gave the following characteristics: color, yellow; burned to a dark red. Taste, fat and grit-

*Ky. Geol. Surv., Bull. No. 6, p. 27.

ty. When ground to 20-mesh and mixed with 37.5 per cent of water, it made a plastic paste, that shrank 12.0 per cent in drying and 5.0 per cent more when vitrified, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strenth of 78 pounds to the square inch, as the average of six tests, with a maximum strength of 98 pounds. Complete vitrification occurred at cone 7 (2,318 degrees F.). This clay did not burn to a very compact body.

CLAY No. 70. The Joseph Lilly and Adjacent Places. The farm of Mr. Joseph Lilly is on the Elizabethtown and Meeting Creek Road, one mile northwest of East View.

On this farm and several adjoining ones there are exposures of a drab plastic clay. The thickness of the deposits could not be accurately determined at any one place, on account of vegetation, but the exposures range from two to six feet at places.

A typical section of these exposures here is as follows:

1.	Big Clifty sandstone	20 ft.
2.	Drab plastic clay	5 ft.
3.	St. Louis limestone at base of hill.	

Similar exposures were found on the land of Mr. Fred Hifner on the south, Schlange Bros. on the east, J. M. Kinkead on the north, and E. R. Robinson on the west.

This is a good quality of drab plastic clay, free from impurities, and possibly valuable for sewers, low grade pottery or earthenware.*

A sample of this clay from the land of the Schlange Bros. gave the following characteristics: Color, yellow and green; greenish-yellow when mixed; burned to a dark red. Taste, fat, and very little grit. Texture, soft, fine-grained, earthy, containing roots. When ground to 20-mesh and mixed with 34.0 per cent of water, it made a plastic paste, that required slow drying, and that shrank 10.0 per cent in drying and 12.0 per cent more when vitrified, giving a total shrinkage of 22.0 per cent. The air-dried mud showed a tensile strength of 22 pounds to the square inch, as the average of two tests. Complete

*Ky. Geol. Surv., Bull. No. 6, p. 23.

vitrification occurred at cone 4 (2,210 degrees F.). Thin pieces warped very badly in burning. This is a very low-grade clay.

CLAY No. 142. This clay is from the farm of Mr. Joseph Lilly, mentioned above under Clay No. 70.

The sample of this clay gave the following characteristics: Color, dark slate; burned yellow at cone 1 (2,102 degrees F.), and reddish-green at higher temperatures. Taste, lean, sour, and gritty. When ground to 20-mesh and mixed with 23.0 per cent of water, it made a paste low in plasticity, that stood rapid drying, and that shrank 5.0 per cent in drying and 7.0 per cent additional when vitrified, giving a total shrinkage of 12.0 per cent. The air-dried mud showed a tensile strength of 59 pounds to the square inch, as the average of six tests, with a maximum strength of 72 pounds. Incipient vitrification occurred at cone 01 (2,066 degrees F.). Complete at cone 7 (2,318 degrees F.). It burned to a good body that will make a fair grade of buff-colored pressed brick.

CLAY No. 61. The Charles Nelson and James Lasley Places. This land is along the Summit and Webb's Mill Road, about two and a half miles from Summit, Hardin county, Ky. The clay is a green earth from the base of the Big Clifty.

A sample of this clay gave the following characteristics: Color, yellowish-green; when burned, the color was dark red. Taste, lean, sour, and some grit. Texture, earthy, containing roots and fibers.

When ground to 30-mesh and mixed with 20.0 per cent of water, it made a paste that was not very plastic, that required slow drying, and that shrank 8.0 per cent in drying and 7.0 per cent more when vitrified. The air-dried mud showed a tensile strength of 32 pounds to the square inch, as the average of three tests. Complete vitrification occurred at cone 6 (2,282 degrees F.). This clay warped and cracked very badly in burning and has no commercial value.

CLAY No. 62. The Gideon McClure Place. This land is on the White Mills and Millerstown Road, two and a half miles north of Millerstown, Hardin, county, Ky. Geological position, St. Louis.

A sample of this clay gave the following characteristics: Color, yellow and green; mixed, the color was

green with a yellowish tint; burned to a dark red, becoming brown when fused. Texture, shaly, coarse-grained. When ground to 30-mesh and mixed with 20.0 per cent of water, it made a lean paste, that required slow drying, and that shrank 5.0 per cent in drying. The clay was nearly fused at cone 6 (2,282 degrees F.). This is a very low-grade clay.

CLAY No. 55. The Taylor Jeffries Place. Mr. Jeffries' farm is one and a half miles north of East View, adjacent to and east of the I. C. R. R.

At the foot of a high hill in the central part of his farm and on other hills at the same elevation just east of there the following section is exposed:

1.	Big Clifty sandstone	30 ft.
2.	Drab and yellow plastic clay	15 ft.
3.	Drab plastic clay	7 in.
4.	Oolitic limestone	12 ft.

The various colors, if ground together, ought to produce a material which would make a nice brick or tiling. The deposit is free from sand or gravel and probably does not contain enough iron to injure it, though there is enough to cause the product to burn red or brownish, perhaps.*

A sample of this clay gave the following characteristics: Color when ground and mixed, bluish-drab; burned to dark red and then to dark brown. Taste, fat, slightly sour, and no grit. Texture, soft, fine-grained, and contained some roots. When ground to 30-mesh and mixed with 26.0 per cent of water, it made a plastic paste, that required rather slow drying, and that shrank 8.0 per cent in drying and an additional 5.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 96.7 pounds to the square inch, as the average of four tests, with a maximum strength of 125 pounds. This clay warped much in burning, when in thin plates, and cracked badly. Complete vitrification occurred at cone 5 (2,246 degrees F.). This is a low-grade clay of very little commercial value except for making common brick.

CLAY No. 151. A sample of the drab clay from the farm of Mr. Taylor Jeffries gave the following charac-

*Ky. Geol. Surv., Bull. No. 6, p. 23.

teristics: Color, yellowish-brown; burned to a dark red. Taste, fat, and gritty. When ground to 20-mesh and mixed with 32.0 per cent of water, it made a plastic paste, that shrank 7.0 per cent in drying and 3.0 per cent more when vitrified, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 91 pounds to the square inch, as the average of six tests, with a maximum strength of 108 pounds. Complete vitrification occurred at cone 5 (2,246 degrees F.), with a tendency to puff up at even lower temperatures. This is a low-grade clay that will be of no use except for common brick.

HENDERSON COUNTY.

CLAY NO. 105. Sample of fire clay, or under clay, of Baskett coal, Baskett Mine, Pittsburgh Coal Co., Henderson county, Ky. Clay, three to three and a half feet thick.

The sample consisted of a few rather large lumps of blue slate such as is found in coal mines.

Analysis of Air-Dried Sample.

	Percent.
Moisture at 100° C.	4.05
Combined water	7.61
Silica	51.96
Alumina	22.14
Ferric oxide	1.47
Ferrous oxide	1.87
Calcium oxide	0.90
Magnesium oxide	2.19
Potassium oxide	4.25
Sodium oxide	0.92
Titanium dioxide	0.80
Sulphur trioxide	0.24
Iron sulphide	1.36
Phosphorous pentoxide	tr.
Total	99.76

The analysis shows that this is a very impure clay.

A sample of this clay gave the following characteristics: Color, dark gray; burned to a yellow. Taste, fat, and somewhat gritty. Texture, soft and fine-grained. When ground to 20-mesh and mixed with 24.0 per cent

of water, it made a plastic paste, that shrank 5.0 per cent in drying. The air-dried mud showed a tensile strength of 84 pounds to the square inch. The clay puffed up very much at cone 1 (2,102 degrees F.,) and is of little or no value for the manufacture of clay products.

CLAY No. 107. No. 9, fire clay or under clay, Spottsville Mine, Green River Coal Co., Henderson county, Ky. Depth about 53 feet to the top of the fire clay. Average thickness, four feet (eighteen inches to six feet).

Sample consisted of medium size lumps of dark gray clay with some fine clay. The sack containing the clay also contained coal No. 3109.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	3.87
Combined water	6.34
Silica	60.20
Alumina	20.60
Ferric oxide	1.04
Ferrous oxide	1.46
Calcium oxide	tr.
Magnesium oxide	1.86
Potassium oxide	2.93
Sodium oxide	1.01
Titanium dioxide	0.80
Sulphur trioxide	tr.
Phosphorus pentoxide	none
Total	100.13
Ratio of Iron and Alumina to Silica	2.60

The analysis shows that this clay would not be very refractory as a fire clay. It ought to make a good building brick. It could also be used in connection with limestone for making Portland Cement.

A sample of this clay gave the following characteristics: Color, very dark, greenish-gray; burned yellow. Taste, fat, and smooth. Texture, soft and fine-grained. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a plastic paste, that shrank 6.0 per cent in drying. The air-dried mud showed a tensile strength of 72 pounds to the square inch. The clay puffed up and cracked badly in burning, even at low temperatures, and is practically worthless.

CLAY No. 103. Under clay from Smith Mills Mine, Henderson county, Ky. Depth to clay, 180 feet.

Average sample of the clay such as is often found in coal mines.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.98
Combined water	7.49
Silica	60.98
Alumina	20.89
Ferric oxide	0.64
Ferrous oxide	1.15
Calcium oxide	tr.
Magnesium oxide	1.72
Potassium oxide	0.82
Titanium dioxide	0.75
Sulphur trioxide	tr.
Phosphorus pentoxide	tr.
Total	100.36
Ratio of Alumina and Iron to Silica	2.67

The analysis shows that this clay would not be very refractory as a fire clay, might have some use as a building brick. It could also be used in connection with a pure limestone for making Portland Cement.

A sample of this clay gave the following characteristics: Color, dark, bluish-gray; burned yellow. Taste, fat and smooth. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 32.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying. The air-dried mud showed a tensile strength of 63 pounds to the square inch. The clay puffed up and cracked very badly at cone 1 (2,102 degrees F.), and is of no value for the manufacture of clay products.

CLAY No. 115. (Chemist's No. 3147.) Under clay, Bluff City, Henderson county, Ky. From John Archbold Coal Co.

Sample of dark gray fire clay very much like sample No. 3145 (Clay No. 107).

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	3.93
Combined water	7.53
Silica	53.92
Alumina	23.38
Ferric oxide	0.16
Ferrous oxide	1.87
Calcium oxide	tr.
Magnesium oxide	2.10
Potassium oxide	4.09
Sodium oxide	0.91
Titanium dioxide	0.80
Sulphur trioxide	0.23
FeS_2	1.09
Phosphorus pentoxide	tr.
Total	100.01
Ratio of Iron and Alumina to Silica	2.10

A sample of this clay gave the following characteristics: Color, very dark gray; burned to a reddish-brown. Taste, fat, sour, free from grit. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 31.0 per cent of water, it made a plastic paste, that shrank 9.0 per cent in drying. The air-dried mud showed a tensile strength of only 10 pounds to the square inch. In burning, the clay puffed up and cracked so badly that it has no value in the manufacture of clay products.

CLAY No. 117. (Chemist's No. 3148.) Under clay from Zion Coal Company, Henderson county, Ky. Clay 1,200 feet southeast of opening and 120 feet deep.

Average sample of dark gray clay or slate such as is found in coal mines; containing plant impressions.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.97
Combined water, etc.	9.10
Silica	55.52
Alumina	21.68
Ferric oxide	none
Ferrous oxide	1.66
Calcium oxide	tr.
Magnesium oxide	1.47

	Per cent.
Potassium oxide	3.31
Sodium oxide	0.95
Titanium dioxide	0.80
Sulphur trioxide	0.83
FeS_2	2.91
Phosphorus pentoxide	tr.
Total	100.20

Quite an impure clay. It would probably be improved in quality by washing to remove the pyrite, after which it might answer for Portland Cement making.

A sample of this clay gave the following characteristics: Color, very dark gray; burned to a yellow. Taste, fat and smooth, quite sour. Texture, soft, fine-grained. When ground to 20 mesh and mixed with 23.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying. The air-dried mud showed a tensile strength of 34 pounds to the square inch. The clay puffed up and cracked badly in burning, even at low temperatures, and it is practically worthless.

HICKMAN COUNTY.

CLAY NO. 8. Fire Clay. This clay is in the "Chalk Banks" of the Mississippi River below Columbus, Hickman county, Ky., and shows a thickness of 35 feet. It occurs in the Wilcox Formation, Eocene Series, Tertiary System. This clay is the upper portion of a deposit somewhat over 45 feet thick; the lower portion of this bed being described below under Clay No. 14.

A sample of this clay gave the following characteristics: Color when dry, light gray, becoming darker gray when wet; burned, the color was a beautiful light shade of yellow, or cream, and this color was perfectly constant at all temperatures. This is a hard clay that is very difficult to disintegrate by prolonged shaking in water. Taste, mildly fat and very gritty. Texture, hard, coarse-grained, massive, and uniform.

When ground to 20-mesh and mixed with 32.0 per cent of water, it made a rather lean, to mildly plastic, paste, that shrank none in drying and only 2.5 per cent in burning. The tensile strength was 48 pounds to the square inch, as shown by the average of nine tests, with

a maximum strength of 56 pounds. No indication of vitrification was shown at cone 11 (2,462 degrees F.).

This is an excellent grade of semi-plastic fire clay.

CLAY No. 14. This clay is from the "Chalk Banks" on the Mississippi River bluffs, about two miles south of Columbus, Hickman county, Ky. This represents the lower portion of the clay deposit just described under Clay No. 8. This is the ten feet of clay directly under Clay No. 8.

A sample of this clay gave the following characteristics: Color, when dry, gray, becoming darker gray when wet; when burned, it became a pretty cream color which is exactly the same shade as Clay No. 8, and equally constant at all temperatures. Taste, fat, and very little grit. Texture, soft, fine-grained and uniform. When disintegrated by prolonged shaking in water, only a little detritus remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 23.0 per cent of water, it made an exceedingly plastic paste, that was rather sticky to handle, and that required rather slow drying. Shrinkage in drying was 10.0 per cent, and none in burning, giving a total shrinkage of 10.0 per cent. Incipient vitrification occurred at cone 9 (2,390 degrees F.), complete at cone 11 (2,462 degrees F.).

This clay will make a beautiful pressed brick, maintaining the same cream color at all temperatures.

JEFFERSON COUNTY.

CLAY No. 27. This clay is from River View, Jefferson county, Ky. Kentucky Cement Works. Geological position, Waverly.

A sample of this clay gave the following characteristics: Color, gray, containing yellow spots; mixed, yellowish-gray; orange-red when burned to cone 1 (2,102 degrees F.); reddish-brown at cone 6 (2,282 F.); and grayish-brown at higher temperatures. Taste, lean, sour, and gritty. Texture, soft, coarse-grained. When disintegrated by prolonged shaking in water, some detritus containing limonite, remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 24.0 per cent of water, it made a slightly plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and 4.0 per cent more when vitrified, giving a total shrinkage

of 11.0 per cent. The air-dried mud showed a tensile strength of 103.2 pounds to the square inch, as the average of five tests, with a maximum strength of 107.5 pounds. Incipient vitrification occurred at cone 1 (2,102 degrees F.), complete at cone 6 (2,282 degrees F.), and partially viscous at cone 9 (2,390 degrees F.). This clay will do for the manufacture of common brick and drain tile.

JESSAMINE COUNTY.

CLAY No. 109. (Chemist's No. 3176.) Clay material from one-fourth mile northeast of High Bridge, Jessamine county, Ky. Sent by J. R. Darman, of the American Stone Ballast Company.

Sample consisted of a medium sized hand specimen brought by L. E. Nollau. Bed from three to four feet thick, overlaid by limestone. The clay had a bluish-green color which changes to white in the blast lamp—quite fusible.

Analysis of Air Dried Sample.

	Per cent.
Moisture at 100° C.	4.01
Ignition	6.44
Silica	53.52
Alumina	19.67
Ferric oxide	1.92
Ferrous oxide	tr.
Calcium oxide	2.32
Magnesium oxide	4.81
Potassium oxide	6.71
Sodium oxide	0.32
Titanium dioxide	0.20
Sulphur trioxide	tr.
Phosphorus pentoxide	0.15
Total	100.07

The sample gave the following characteristics: Color, green; burned to yellowish-gray, changing to green when viscous. Taste, rather lean and smooth. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a mildly plastic paste, that shrank 6.0 per cent in drying and 7.0 per cent additional when vitrified. It slacked very rap-

idly in water. The air-dried mud showed a low tensile strength, only 11 pounds to the square inch. Complete vitrification occurred at cone 02 (2,030 degrees F.), and viscosity at cone 6 (2,282 degrees F.). This is a fair grade of green slip clay.

CLAY No. 87. (Chemist's No. 3200.) The Buckner Bryant Place. This farm is nine miles south of Lexington, on the Nicholasville Road, in Jessamine county, Ky. Thickness of bed, from three to four feet.

Sample consisted of hand specimen, weighing about one pound, of gray clay. Stained in places with iron.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.57
Combined water	5.26
Silica	58.40
Alumina	17.48
Ferric oxide	4.64
Ferrous oxide	0.58
Calcium oxide	2.86
Magnesium oxide	1.92
Potassium oxide	4.26
Sodium oxide	0.59
Titanium dioxide	0.60
Sulphur trioxide	none
Phosphorus pentoxide	0.80
Total	99.96
Ratio of Iron and Alumina to the Silica	2.57

The analysis of this clay shows that it could be used in making Portland Cement, though the potassium oxide is high. It would make brick and possibly drain tiles, etc.

A sample of this clay, brought in by Mr. Buckner Bryant, gave the following characteristics: Color, yellow; burned to dark red. When ground to 20-mesh and mixed with 34.0 per cent of water, it made a fat paste, that stood a moderately rapid rate of drying, and that shrank 5.0 per cent in drying. The air-dried mud showed a tensile strength of 90 pounds to the square inch, with a maximum strength of 126 pounds. The clay puffed up very badly at cone 1 (2,102 degrees F.). It is a very low-grade clay.

CLAY No. 88. (Chemist's No. 3201.) This clay is from the same deposits as Clay No. 87, on the farm of Mr. Buckner Bryant.

The following analysis of an air-dried sample shows practically the same composition as Clay No. 87.

	Per cent.
Moisture at 100° C.	2.52
Combined water	5.60
Silica	58.80
Alumina	17.44
Ferric oxide	5.28
Ferrous oxide	0.58
Calcium oxide	2.40
Magnesium oxide	1.68
Potassium oxide	3.93
Sodium oxide	0.81
Titanium dioxide	0.70
Sulphur trioxide	none
Phosphorus pentoxide	0.90
Total	100.64
Ratio of Iron and Alumina to Silica	2.59

The chemist commented on this clay as follows: "The analysis of this clay shows that it has the composition for a Portland Cement clay, though the potassium oxide is rather high. It should also made brick and possibly drain tile."

The physical tests showed this clay to be about like Clay No. 87 and of a low grade. It became viscous at cone 5 (2,246 degrees F.).

CLAY No. 94. Sample of clay sent by E. C. Beggs, Nicholasville, Ky. The sample consisted of several rather large lumps of white clay, somewhat streaked with iron.

Analysis of Air-dried Sample:	Per cent.
Moisture at 100° C.	1.81
Combined water	7.85
Silica	53.60
Alumina	27.04
Ferric oxide	3.52
Ferrous oxide	tr.
Calcium oxide	tr.

	Per cent.
Magnesium oxide	1.19
Potassium oxide	3.57
Sodium oxide	0.37
Titanium dioxide	0.80
Sulphur trioxide	tr.
Phosphorus pentoxide	tr.
Total	99.75

The analysis shows that this clay is of medium quality and probably could be used in brick making, drain tiles and low-grade pottery.

The sample gave the following characteristics: Color, green; burned to a pinkish-yellow at cone 1 (2102° F.), changing to green at cone 9 (2390° F.). Taste, fat, sour, and no grit. Texture, soft, and very fine-grained. When ground to 20-mesh and mixed with 36.0 per cent of water, it made a very plastic paste, that shrank 5.0 per cent in drying, and 8.5 per cent more when vitrified, giving a total shrinkage of 13.5 per cent. The air-dried mud showed a tensile strength of 59 pounds to the square inch. It was fully vitrified at cone 6 (2,282 degrees F.), with no indication of viscosity at cone 9 (2,390 degrees F.). This clay would do for the manufacture of terra cotta, or would make a pretty pressed brick.

Larue-Taylor Boundary.

Clay No. 49. The Thomas J. Hash property. This property is in Taylor county, but borders on the Larue county boundary to the north. Mr. Hash is the owner of a small store on the boundary line, at which is located the postoffice known as Hibernia. On land owned by Mr. Hash, at a point about one-hundred and fifty yards south of his store and dwelling, there is an exposure of excellent clay. This exposure is along a spring branch which flows out at the base of the Conglomerate Sandstone. The question naturally arises, is the spring a result of the clay deposit which the water encounters on passing down through the Conglomerate, or is the clay deposit a result of deposition by the spring? The former seems to be the true condition. In the first place, if the deposit were formed by the spring branch, one

would expect the bed to contain alternating layers of gravel and sand from top to bottom. As a matter of fact, borings show that the sand and gravel occur only at the surface. The surface sand and gravel form the spring bed resting on the clay deposit at this point. The gravel is the result of concentration of pebbles from decay of the Conglomerate Sandstone; the sand cementing the pebbles is broken loose by continued exposure to the atmospheric agencies and washed away, leaving the quartz pebbles quite thickly scattered over the surface. At places this gravel has been accumulated to a considerable amount and may easily be mistaken for old river deposits.

Again, that the clay is not residual from spring water is shown by the fact that clay is found at the same elevation across a ravine to the east and also on the opposite side of the ridge on property belonging to Mr. T. J. Nelson. This ridge runs to a height of from seventy-five to one hundred and twenty feet above the clay level. The latter exposures are in no way related to the spring branch mentioned above.

At the first mentioned exposure along the branch, work with a post-hole digger and auger revealed the following section:

	Ft.	In.
1. Bluish sand and gravel	2	0
2. Brownish clay	3	4
3. Very white clay	0	10
4. White clay, slightly stained yellow	11	0
5. Bottom of boring.		

The quantitative analysis of layer No. 3, as made by Burk and Lyon, follows:

	Per cent.
Hygroscopic water	3.82
Combined water	12.10
Silica	49.14
Alumina	32.24
Iron oxide (Fe_2O_3)	1.40
Lime	0.61
Magnesia	0.09
Sulphur trioxide	0.24
Alkalies	1.26
Titanium dioxide	0.01
Total	100.91

The rational analysis of the above clay, made by Burk and Lyon, follows:

Clay substance	82.75
Quartz	16.06
Feldspathic detritus	1.19
Total	100.00

The quantitative analysis of layer No. 4, made by Burk and Lyon, follows:

	Per Cent.
Hygroscopic water	2.71
Combined water	15.66
Silica	43.64
Alumina	34.57
Iron oxide (Fe_2O_3)	2.01
Lime	0.99
Magnesia	0.10
Sulphur trioxide	0.53
Alkalies	0.81
Titanium dioxide	tr.
Total	101.02

Following is the rational analysis of the above clay, also made by Burk and Lyon:

	Per cent.
Clay substance	93.67
Quartz	5.19
Feldspathic detritus	1.14
Total	100.00

In layer No. 4, there are occasional hard white particles of clay which on slight notice may be taken for gravel. They may be scratched with the finger-nail, however, and would possibly be of no serious detriment to the clay proper. These particles are due no doubt to a different percentage of combined water in their make-up.*

A sample of this clay was labeled, "Thomas Hash Place, borings from exposure on Mr. J. H. Despain line

*Ky. Geol. Surv., Bull. No. 6, pp. 55-58. For further discussion see same reference, p. 54.

to the south." This sample gave the following characteristics: Color, a mixture of white and yellow; pale yellow when ground and mixed; when burned, the color was yellowish-gray up to cone 6 (2,282 degrees F.), becoming a dark gray, peppered with white specks, at higher temperatures. Taste, fat and gritty. Texture, soft, coarse and fine-grained, irregular—some portions are kaolin, others are sandy, while some clear quartz particles are present (these quartz particles will cut glass).

When ground to 30-mesh and mixed with 35.0 per cent of water, it made a fat paste, that stood rapid drying, and that shrank 9.0 per cent in drying and an equal amount when vitrified, giving a total shrinkage of 18.0 per cent.

The air-dried mud showed a tensile strength of 103 pounds to the square inch, as the average of four tests, with a maximum strength of 131.8 pounds. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 7 (2,318 degrees F.). The clay burned to a hard, compact body free from warping when in thin pieces. This is a high-grade clay for terra cotta, pressed brick, and would make a pretty floor tile.

CLAY NO. 59. This clay represents borings from exposure No. 1, near the dwelling of Mr. Thos. Hash, as noted above under Clay No. 49.

A sample of this clay gave the following characteristics: Color, pale yellow; burned to cone 1 (2,102 degrees F.), the color was a beautiful pink, changing to a white and losing all the pink tint at cone 7 (2,318 degrees F.). Taste, fat, and very little grit. Texture, soft, and medium-grained, uniform and compact.

When ground to 30-mesh and mixed with 36.0 per cent of water, it made a paste of fair plasticity, that stood rapid drying, and that shrank 5.0 per cent in drying and 12.0 per cent more in burning, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strength of 63 pounds to the square inch, as the average of three tests, with a maximum strength of 70 pounds. Incipient vitrification occurred at cone 5 (2,246 degrees F.), but was not complete at cone 9 (2,390 degrees F.). It burned to a hard, compact body, without warping when in thin pieces.

This is a semi-refractory clay that could be used in the manufacture of terra cotta. As a stoneware clay, it lacks the proper toughness and plasticity to permit of its being turned on a potter's wheel, but these physical qualities could be supplied in a mixture, thus making the clay suited to the manufacture of stoneware.

CLAY No. 64. Clay collected from surface exposure on the Thomas Hash land. Geological position, base of Conglomerate.

This sample gave the following results: Color, mostly white but containing green and yellow to a slight extent; burned nearly white. Taste, very plastic, and gritty. Texture, soft, irregular. When ground to 30-mesh and mixed with 37.0 per cent of water, it made a very plastic paste, that shrank 10.0 per cent in drying and a like amount in burning to cone 7 (2,318 degrees F.), giving a total shrinkage of 20.0 per cent. Incipient vitrification occurred at cone 5 (2,246 degrees F.), but not complete at cone 7 (2,318 degrees F.). This is a kaolin of a fair quality, but it is not suited to the manufacture of porcelain.

CLAY No. 89. Chemist's No. 3127.) Clay, Hibernia, Taylor-Larue Line. Base of Conglomerate. Soil, one foot; sand and water, four and one-half feet; clay, three and one-half feet deep (as deep as auger went). T. J. Nelson place.

Average sample of very fragile clay containing some quartz pebbles. Non-fusible and plastic.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.85
Combined water	15.02
Silica	43.40
Alumina	36.89
Ferric oxide	0.48
Ferrous oxide	0.22
Calcium oxide	none
Magnesium oxide	0.43
Sulphur trioxide	tr.
Phosphates and carbonates	none
Potassium oxide	0.21
Titanium dioxide	0.15
Total	100.30
Ratio of Iron and Alumina to Silica	1.15

A fine plastic fire clay or nearly pure kaolin.

A sample of this clay gave the following characteristics: Color, pure white, and remained so when burned. Taste, lean and gritty. Texture, soft, fine-grained. When ground to 20-mesh and mixed with 36.0 per cent of water, it made a mildly plastic paste, that shrank 8.0 per cent in drying, and a like amount when burned, giving a total shrinkage of 16.0 per cent. The air-dried mud showed a tensile strength of 34.5 pounds to the square inch (one test only). It burned to a hard, granular body, and showed practically no indication of vitrification at cone 11 (2,462 degrees F.). This is a beautiful white-burning refractory clay.

CLAY NO. 111. (Chemist's No. 3116.) Clay "Hibernia," Larue-Taylor line. Base of Conglomerate. John Hedgpath, three miles southeast of Hibernia.

Average sample of white clay consisting of small lumps for the most part, also contained some lumps streaked with iron which had a sandy feel. Slightly plastic and non-fusible in blow-pipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.80
Combined water	12.21
Silica	52.54
Alumina	30.18
Ferric oxide	1.12
Ferrous oxide	0.58
Calcium oxide	tr.
Magnesium oxide	1.16
Potassium oxide	0.83
Sodium oxide	0.31
Titanium dioxide	0.10
Sulphur trioxide	none
Phosphorus	none
Carbonates	none
Total	100.83
Ratio of Iron and Alumina to Silica	1.64

A sample of this clay gave the following characteristics: Color, pinkish-white; burned to pink and then, at higher temperature, to a grayish-white. Taste, fat,

some grit. Texture, soft, coarse and fine-grained. When ground to 20-mesh and mixed with 31.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying and an additional 9.0 at cone 9 (2,390 degrees F.), giving a total shrinkage of 16.0 per cent. The air-dried mud showed a tensile strength of 52 pounds to the square inch. This is a high-grade clay for the manufacture of light colored pressed brick.

CLAY No. 108. (Chemist's No. 3115.) Clay near Hibernia, Larue-Taylor line. Base of Conglomerate. John Bulay farm, one mile northeast of Badger. Clay in Larue county.

Average sample of yellow sedimentary clay having a rather sandy feel, a clay odor, plastic, slightly fusible in blow-pipe flame, and containing a trace of ferrous iron.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.82
Combined water	7.70
Silica	66.00
Alumina	13.40
Ferric oxide	8.00
Ferrous oxide	tr.
Calcium oxide	tr.
Magnesium oxide	1.31
Potassium oxide	1.63
Sodium oxide	0.37
Titanium dioxide	0.50
Total	100.73
Ratio of Iron and Alumina to Silica	3.09

The ratio is right for a Portland Cement clay.

A sample of this clay gave the following characteristics: Color yellow; burned dark red. Taste, fairly fat, and quite gritty. Texture, soft, coarse and fine-grained. When ground to 20 mesh and mixed with 31.0 per cent of water, it made a mildly plastic paste, that shrank 12.0 per cent in drying, and 7.0 per cent additional when vitrified, giving a total shrinkage of 19.0 per cent. The air-dried mud showed a tensile strength of 114 pounds to

the square inch. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 9 (2,390 degrees F.). This is a good grade of clay for a red-burning pressed brick.

CLAY No. 98. (Chemist's No. 3126.) Clay, Hibernia, Taylor-Larue line, near base of Conglomerate in St. Louis. J. H. Despain, one-half mile south of Thos. Hasbstone.

Average sample of purple colored clay containing a few lumps of yellow clay. Seems to be free from sand and gravel. Plastic and fusible in blow-pipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.75
Combined water	5.19
Silica	63.30
Alumina	14.85
Ferric oxide	10.04
Ferrous oxide	0.36
Calcium oxide	none
Magnesium oxide	0.98
Sulphur trioxide	tr.
Potassium oxide	0.46
Titanium dioxide	0.87
Total	99.63
Ratio of Iron and Alumina to Silica	2.50

The ratio is right for a Portland Cement clay. The iron is high.

A sample of this clay gave the following characteristics: Color, brown, lavender; burned brown. Taste, fat, sour, some grit. When ground to 20-mesh and mixed with 36.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and an additional 5.0 per cent in burning, giving a total shrinkage of 13.0 per cent. The air-dried mud showed a tensile strength of 117 pounds to the square inch. Incipient vitrification occurred at cone 2 (2,138 degrees F.), complete at cone 6 (2,282 degrees F.), and somewhat viscous at cone 9 (2,390 degrees F.). This clay will make good sewer pipe.

CLAY No. 95. (Chemist's No. 3128.) Clay near Hibernia, Larue-Taylor Boundary. St. Louis Horizon.

Clay is residual from kaolin above, 100 feet. Mrs. Martha Underwood and Jas. C. Scaggs.

Average sample of red clay for the most part, some yellow and white, mixed. Plastic and fusible.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.43
Combined water	4.83
Silica	65.20
Alumina	13.76
Ferric oxide	8.88
Ferrous oxide	0.50
Calcium oxide	tr.
Magnesium oxide	1.59
Sulphur trioxide	none
Potassium oxide	3.17
Sodium oxide	0.39
Titanium dioxide	0.80
Total	100.55
Ratio of Iron and Alumina to Silica	2.81

The ratio is right for a Portland Cement, but the iron is high.

A sample of this clay gave the following characteristics: Color, pink to reddish-yellow; burned to a very dark red. Taste, fat and gritty. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a plastic paste, that shrank 8.0 per cent in drying and a like amount additional when vitrified, giving a total shrinkage if 16.0 per cent. The air-dried mud showed a tensile strength of 65 pounds to the square inch. The clay burned to a very hard, compact body when vitrified, which stage was reached at cone 01 (2,066 degrees F.). The clay had swollen up at cone 6 (2,282 degrees F.), but showed very little tendency to become viscous. This is not a very good clay.

LEWIS COUNTY.

CLAY No. 163. "Fire clay. Sample from 11-foot of 14-foot bed, sample being obtained from one foot to 13 feet below top of bed. This forms top part of Alger formation. Verner Dryden Place, three-fourths miles

north-northwest of Penn Station, Lewis county, Ky. Nearly west of Dryden's house and from just below base of West Union formations. Face of exposure weathered."

A sample of this clay gave the following characteristics: Color, light gray to green; burned dark red. Taste, fat and smooth. When ground to 20-mesh and mixed with 26.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying and a like amount additional in vitrifying, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 60 pounds to the square inch, as the average of ten tests, with a maximum strength of 84 pounds. Complete vitrification occurred at cone 2 (2,138 degrees F.), viscosity at cone 8 (2,354 degrees F.). This is a good common-brick clay.

CLAY No. 162. "Estill shale, 404 R. from Carr's Fork of River Road."

A sample of this shale gave the following characteristics: Color, light brown; burned to dark red. Taste, fat and smooth. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a very plastic paste, that shrank 5.0 per cent in drying and a like amount in vitrifying, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 68 pounds to the square inch, as the average of nine tests, with a maximum strength of 84 pounds. Complete vitrification occurred at cone 1 (2,102 degrees F.). This is a common-brick or drain-tile clay.

CLAY No. 164. "Blue shale which cuts into gray shale as a lentil at Firebrick, Lewis county, Ky. Portsmouth Granite Brick Co."

A sample of this clay gave the following characteristics: Color, green, burned dark red. Taste, fat and smooth. When ground to 20-mesh and mixed with 24.0 per cent of water, it made a plastic paste that shrank 3.0 per cent in drying and 7.0 per cent additional in vitrifying, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 42 pounds to the square inch as the average of twelve tests, with a maximum strength of 49 pounds. Complete vitrification occurred at cone 01 (2,066 degrees F.). This is an excellent common-brick clay.

CLAY No. 165. "Shale from top of hill, back of Portsmouth Granite Brick Co.'s works, Firebrick, Lewis county, Ky."

A sample of this clay gave the following characteristics: Color, bluish-gray; burned yellow at cone 1 (2,102 degrees F.), slightly yellow at cone 7 (2,318 degrees F.), and green at cone 9 (2,390 degrees F.). Taste, fat and smooth. When ground to 20-mesh and mixed with 26.0 per cent of water, it made a plastic paste, that stood a rapid rate of drying, and that shrank 3.0 per cent in drying and 6.0 per cent more when vitrified, giving a total shrinkage of 9.0 per cent. The air-dried mud showed a tensile strength of 53 pounds to the square inch, as the average of three tests, with a maximum strength of 66 pounds. Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 8 (2,354 degrees F.). It burned to a hard, compact body, free from warping when in thin pieces. This is a high-grade clay for stoneware or terra cotta.

CLAY No. 161. "Sample of red shale just below yellow, greenish-brown argillaceous sandstone ledge, and 2 feet of gray shale, then 6½ feet of red. Sample 2½ feet of middle portion. Near Fruet, Lewis County, Ky."

A sample of this clay gave the following characteristics: Color, dark brown; burned to dark red. Taste, fat and smooth. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying, and a like amount in vitrifying, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 77 pounds to the square inch, as the average of four tests, with a maximum strength of 89 pounds. Complete vitrification occurred at cone 01 (2,066 degrees F.). It burned to a good body and will make an excellent common brick or drain tile.

LEWIS AND CARTER LINE.

CLAY No. 153. "Fire clay from Alford Jordan place."

A sample of this clay gave the following characteristics: Color, gray-slate; burned to a creamy-white. Taste, lean, gritty. Texture, hard, and rock-like. When ground to 20-mesh and mixed with 13.0 per cent of water,

it made a paste that was exceedingly low in plasticity, and that fell to pieces quite easily. The paste shrank 3.0 per cent in drying and 4.0 per cent additional in burning, giving a total shrinkage of 7.0 per cent. It showed very little tensile strength—only from three to five pounds to the square inch. There was but slight indication of vitrification at cone 11 (2,462 degrees F.). This is a fair grade of flint fire clay.

LIVINGSTON COUNTY.

CLAY NO. 148. The Daniel and James Cork Place. This place is located at Grand Rivers, Livingston County, Ky. The clay occurs at the base of LaFayette Conglomerate.

A sample of this clay gave the following characteristics: Color, gray; burned to a pinkish—to red-gray. Texture, sandy. Taste, exceedingly lean and wholly gritty. When ground to 20-mesh and mixed with 16.0 per cent of water, it made a paste that was almost wholly wanting in plasticity, and that showed practically no tensile strength. The paste shrank none in drying or burning, but expanded slightly in burning. It burned to a granular body with no indication of vitrification at cone 11 (2,462 degrees F.).

This is a high-grade fire sand that would be useful in the construction of retort furnaces where fluctuations of temperature would destroy fire brick. This fire-sand lining is known as Dinas brick.

CLAY NO. 140. The J. E. Williamson Place, Livingston County, Ky. This land, owned by Mr. J. E. Williamson, of Paducah, is about two miles north of Grand Rivers and a half a mile east of Gravel Switch. Here there is an exposure of beautiful white clay. The deposit is of comparatively recent formation, belonging to the Quaternary period, which covered the area of Kentucky west of the Cumberland and Tennessee rivers, and at some places is found crossing these rivers. The clay is between the two rivers.

At the exposure, which is along a bold ridge, a shaft had been sunk, but it had become filled before the examination was made. According to information given by Mr. Williamson, the shaft was over thirteen feet deep and

did not pierce the entire thickness of the deposit. Following is the section at the exposure:

1.	Soil and gravel	3 ft.
2.	White clay	13 ft.
3.	Covered	12½ ft.
4.	Bluish limestone	2 ft.

This will probably prove to be a valuable deposit. The horizontal extent of the bed could not well be determined, because of timber growth around the ridge in which the clay is exposed.

The following analysis, made for the survey by Burk and Lyon, indicate a relatively pure refractory clay of high quality:

	Per cent.
Hygroscopic moisture	0.50
Combined water	3.81
Silica	83.47
Alumina	8.20
Ferric oxide	1.16
Lime	0.69
Magnesia	0.12
Potash and soda	0.74
Titanium dioxide	0.83
Sulphur trioxide	0.28
Total	99.80

The Rational Analysis is:

Clay substance	33.03
Quartz	64.43
Feldspathic detritus	2.54
Total	100.00(*)

A sample of this clay gave the following characteristics: Color, almost white, slightly gray; burned almost pure white. Taste, fat and gritty. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and none in burning, giving a total

*Ky. Geol. Surv., Bull. No. 6, pp. 141 and 142.

shrinkage of 5.0 per cent. The air-dried mud showed a tensile strength of 35 pounds to the square inch, as the average of six tests, with a maximum strength of 42 pounds. The clay warped some in drying and in burning. It burned to a hard, compact body. Incipient vitrification occurred at cone 7 (2,318 degrees F.), complete at cone 11 (2,462 degrees F.). This is a high-grade semi-refractory clay, that will make a most beautiful white pressed brick or a high grade terra cotta.

MARSHALL COUNTY.

CLAY No. 101. (Chemist's No. 3123.) L. Faust clay, two miles east of Palma, near Palma and Birmingham Road. Lower Quaternary. Marshall County, Ky.

Average sample of light gray clay containing spots of iron and some sand. Slightly plastic and non-fusible in blow-pipe flame.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.93
Combined water	8.86
Silica	55.90
Alumina	26.34
Ferric oxide	2.24
Ferrous oxide	0.28
Calcium oxide	tr.
Magnesium oxide	1.01
Sulphur trioxide	tr.
Potassium oxide	1.89
Sodium oxide	0.33
Titanium dioxide	1.00
Phosphates and carbonates	none
Total	99.78
Ratio of Iron and Alumina to Silica	1.93

A sample of this clay gave the following characteristics: Color, bluish-drab; burned to a yellowish-gray, becoming gray when vitrified. Taste, fat, very little grit. Texture, soft, and mostly fine-grained. When ground to 20-mesh and mixed with 29.0 per cent water, it made a fairly plastic paste, that shrank 5.0 per cent in drying and 9.0 per cent additional when vitrified, giving a total

shrinkage of 14.0 per cent. The air-dried mud showed a tensile strength of 63 pounds to the square inch. Incipient vitrification occurred at cone 5 (2,246 degrees F.), complete at cone 9 (2,390 degrees F.). It burned to a hard, compact body, free from warping. This is a rather high-grade clay that would make a good yellowish-gray pressed brick or terra cotta.

CLAY NO. 96. (Chemist's No. 3122.) Wm. Bunadell Place. This place is near the Bryantsburg and Gilbertsville Road, about two and a half miles north of Bryantsburg, Marshall County, Ky. Base of Quaternary.

Average sample of white clay on the exterior, but presenting dark bands when broken. Contains mica scales and is rather sandy. Non-fusible in blow-pipe flame. Slightly plastic.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.10
Combined water	6.89
Silica	65.10
Alumina	22.18
Ferric oxide	1.28
Ferrous oxide	0.28
Calcium oxide	tr.
Magnesium oxide	0.80
Sulphur trioxide	none
Potassium oxide	1.38
Sodium oxide	0 37
Titanium dioxide	1.12
Phosphates and carbonates	none
Total	100.50
Ratio of Iron and Alumina to Silica	2.78

A sample of this clay gave the following characteristics: Color, light gray; burned almost white. Taste, fat and somewhat gritty. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a very plastic paste, that shrank 5.0 per cent in drying, and an additional 5.0 per cent when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 55 pounds to the square inch. The clay burned to a hard, compact, white

body. Incipient vitrification occurred at cone 9 (2,390 degrees F.), with very little change at cone 11 (2,462 degrees F.). This is a white-burning refractory clay of excellent quality.

CLAY No. 91. (Chemist's No. 3120.) This is another sample from the same locality as Clay No. 96, given above.

Average sample of light gray clay having a soapy feel and clay odor. Quite homogeneous in character. Contained some scales of mica. A good looking specimen of clay. Non-fusible in blow-pipe flame.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.10
Combined water	7.57
Silica	63.20
Alumina	23.32
Ferric oxide	1.22
Ferrous oxide	0.22
Calcium oxide	none
Magnesium oxide	tr.
Potassium oxide	1.41
Sodium oxide	0.32
Titanium dioxide	1.10
Phosphates and carbonates	none
Total	99.46
Ratio of Iron and Alumina to Silica	2.55

The ratio is right for a Portland Cement clay.

A sample of this clay gave the following characteristics: Color, almost white, slightly yellowish; burned to pinkish-white at cone 1 (2,102 degrees F.), becoming more of a yellowish, dirty-white at higher temperatures. Taste, fat and some grit. When ground to 20-mesh and mixed with 17.0 per cent of water, it made a moderately plastic paste, that stood rapid drying, and that shrank 7.5 per cent in drying and a like amount additional in burning to cone 9 (2,390 degrees F.), giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 65 pounds to the square inch. The clay burned to a very hard, compact body. Incipient vitrification occurred at cone 6 (2,282 degrees F.), com-

plete at cone 9 (2,390 degrees F.). This is an excellent semi-refractory clay for earthenware, terra cotta, etc.

CLAY No. 114. (Chemist's No. 3121.) L. Loften clay, Paducah and Benton Road at Scale, Marshall County, Ky. Lower Quaternary.

Average sample of white clay colored in spots by iron, having a sandy feel and containing scales of mica. Plastic and non-fusible in blow-pipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.25
Combined water	8.45
Silica	60.60
Alumina	25.06
Ferric oxide	1.36
Ferrous oxide	0.43
Calcium oxide	none
Magnesium oxide	tr.
Potassium oxide	1.40
Sodium oxide	0.24
Titanium dioxide	1.00
Sulphur trioxide	none
Phosphates and carbonates	none
Total	99.79
Ratio of Iron and Alumina to Silica	2.27

A sample of this clay gave the following characteristic: Color, yellowish-gray, nearly white; burned to a cream-yellow, changing to a muddy-gray at higher temperature. Taste, fat, and a little grit. Texture, soft, fine and coarse-grained. When ground to 20-mesh and mixed with 36.0 per cent of water, it made a very plastic paste, that stood rapid drying, and that shrank 5.0 per cent in drying and 6 per cent more in burning to cone 9 (2,390 degrees F.), giving a total shrinkage of 11 per cent. The air-dried mud showed a tensile strength of 42 pounds to the square inch. Incipient vitrification occurred at cone 6 (2,282 degrees F.), complete at cone 10 (2,426 degrees F.). This is a high-grade clay for the manufacture of terra cotta and stoneware.

McCRACKEN COUNTY.

CLAY No. 26. Ball-clay. This sample was handed in by Dr. J. W. Pryor, of the State University, and was designated by him as No. 1. This sample represenths the upper three feet of a six-foot bed of clay, located about eight miles south of Paducah, McCracken county, Ky., on the Contest Road.

The sample of this clay gave the following characteristics: Color, nearly white when dry, and gray when wet; when burned below cone 8 (2,354 degrees F.), the color was almost white, becoming somewhat gray at cone 9 (2,390 degrees F.). Texture, very soft, fine-grained, massive and uniform. When ground to 20-mesh and mixed with 30.0 per cent of water, it made a very plastic paste, that shrank 5.0 per cent in drying, and 9.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 14.0 per cent.

Incipient vitrification occurred at cone 9 (2,390 degrees F.), complete at cone 11 (2,462 degrees F.). It stood quite rapid dying. There was no checking, cracking or warping in drying and none in burning.

This seems to be an unusually fine quality of ball-clay.

CLAY No. 28. Ball-clay. This sample was handed in by Dr. J. W. Pryor, of the State University, and designated by him as No. 2. This sample represents the lower four feet of the six-foot bed of clay mentioned above under Clay No. 26.

This sample gives the following characteristics: Color, brown when dry, and quite dark brown when wet; when burned below cone 8 (2,354 degrees F.), the color was almost white, becoming very light gray at cone 9 (2.390 degrees F.), and remaining so at cone 11 (2,462 degrees F.). Texture, massive, very soft, fine-grained and uniform; when disintegrated by prolonged shaking in water, practically no detritus remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 31.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying and 12.0 per cent additional when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 17.0 per cent. Incipient vitrification occured at cone 9 (2,390 degrees F.), complete at cone 11 (2,462 degrees

F.). It stood a fair rate of drying. There was no cracking or warping in burning.

This is an excellent quality of ball clay.

CLAY No. 30. Ball-clay. This sample was handed in by Dr. J. W. Pryor, of the State University, and designated by him as No. 3. This sample is from the upper four feet of a six-foot bed of clay about seven and a half miles south of Paducah, McCracken County, Ky., on the Contest Road. Clay No. 34 is from the lower three feet of this same bed.

The sample gave the following characteristics: Color, almost white when dry, and slightly gray when wet. When burned at temperatures below cone 8 (2,354 degrees F.), the color was almost white, becoming a very light gray at cone 9 (2,390 degrees F.). Texture, very soft, massive, fine-grained and uniform. When disintegrated by prolonged shaking in water, practically no detritus remained on the 100-mesh seive.

When ground to 20-mesh and mixed with 31.0 per cent water, it made a very plastic paste, that shrank 5.0 per cent in drying and 13.0 per cent more when burned to cone 9 (2,390 degrees F.), giving a total shrinkage of 18.0 per cent. The tensile strength, as shown by the average of three tests, was 50 pounds to the square inch. Incipient vitrification occurred at cone 9 (2,390 degrees F.), complete at cone 11 (2,462 degrees F.). There was no warping or cracking in burning.

This is a most excellent ball-clay and gives promise of being one of the most important clays in Kentucky.

CLAY No. 34. This sample was brought in by Dr. J. W. Pryor, and represents the lower three feet of the bed of clay described above under Clay No. 30. This sample was designated, by Dr. Pryor, as No. 4.

It gave the following characteristics: Color, brown, both wet and dry; it burned to a light gray at cone 11 (2,462 degrees F.). Taste, fat and no grit. When disintegrated by prolonged shaking in water, no detritus remained on the 100-mesh seive.

When ground to 20-mesh and mixed with 36.0 per cent of water, it made a plastic paste that stood rapid drying, and that shrank 9.0 per cent in drying and a like amount when vitrified, giving a total shrinkage of 18.0 per cent.

The clay was fully vitrified at cone 11 (2,462 degrees F.).

This is an excellent, light-gray-burning clay.

CLAY No. 112. (Chemist's No. 3117.) Victor Welch clay on Loneoak and Mayfield Road, three miles from Loneoak, McCracken County, Ky. Geological position, Lagrange.

Average sample of clay having whitish-blue cast and a sandy feel. Looks like clay usually found in Craw-fish land. Some spots of iron present. Slightly plastic and non-fusible in blow-pipe flame.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	1.07
Combined water	7.20
Silica	69.40
Alumina	18.50
Ferric oxide	1.15
Ferrous oxide	0.29
Calcium oxide	tr.
Magnesium oxide	0.36
Potassium oxide	0.85
Sodium oxide	0.18
Titanium dioxide	0.50
Sulphur trioxide	none
Phosphates and carbonates	none
Total	99.50
Ratio of Iron and Alumina to Silica	3.48

The ratio is right for a Portland Cement clay.

A sample of this clay gave the following characteristics: Color, greenish-gray; burned to a very pale yellow. Taste, fairly plastic, some fine grit. Texture, soft, fine and coarse-grained. When ground to 20-mesh and mixed with 25.0 per cent of water, it made a mildly plastic paste, that stood rapid drying, and that shrank 2.0 per cent in drying and 3.0 per cent in burning to cone 9 (2,390 degrees F.), giving a total shrinkage of 5.0 per cent.

The air-dried mud showed a tensile strength of 70 pounds to the square inch. It burned to a somewhat

sandy body, and was but slightly vitrified at cone 11 (2,462 degrees F.).

This is a fairly good grade of fire-clay.

CLAY NO. 104. (Chemist's No. 3118.) Richard Bell clay, on Paducah and Mayfield Road, four miles south of Paducah, McCracken County, Ky. Ochreous, plastic clay, base of Lafayette or Stratified Drift of Quaternary. Thickness, six to twelve feet.

Average sample of yellow and white clay, more of the white than of the yellow. Had a soapy feel, plastic and fusible below blow-pipe.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.90
Combined water	8.95
Silica	55.76
Alumina	23.72
Ferric oxide	5.44
Ferrous oxide	0.43
Calcium oxide	tr.
Magnesium oxide	0.92
Potassium oxide	1.74
Sodium oxide	0.32
Titanium dioxide	0.80
Sulphur trioxide	none
Phosphates and carbonates	none
Total	100.98
Ratio of Iron and Alumina to Silica	1.93

A sample of this clay gave the following characteristics: Color, yellow; burned dark red. Taste, fat, and very little grit. Texture, soft and fine-grained. When ground to 20-mesh and mixed with 37.0 per cent of water, it made a plastic paste, that shrank 8.0 in drying and 12.0 per cent additional when vitrified, giving a total shrinkage of 20.0 per cent. The air-dried mud showed a tensile strength of 82 pounds to the square inch. It burned to a hard, compact body. Incipient vitrification occurred at cone 01 (2,066 degrees F.), complete at cone 6 (2,282 degrees F.) This clay will make a fair grade of paving brick.

CLAY No. 110. (Chemist's No. 3119.) Gus Munier clay on Paducah and Mayfield Road, five and a half miles south of Paducah, McCracken County, Ky. Lagrange.

Samples consisted of three rather large-sized lumps of bluish looking clay streaked with brown. Had a soapy feel and clay odor. Plastic and fusible before blow-pipe.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.95
Combined water	8.55
Silica	59.06
Alumina	22.54
Ferric oxide	2.72
Ferrous oxide	0.43
Calcium oxide	none
Magnesium oxide	1.01
Potassium oxide	1.49
Sodium oxide	0.36
Titanium dioxide	0.80
Total	99.91
Ratio of Iron and Alumina to Silica	2.30

A sample of this clay gave the following characteristics: Color, brown when wet; brownish-gray when dry; burned yellowish-brown at cone 6 (2,282 degrees F.), changing to gray, slightly yellowish, at cone 9 (2,390 degrees F.). Taste, fat and smooth. Texture, soft, fine-grained, massive and uniform. When ground to 20-mesh and mixed with 31.0 per cent of water, it made a plastic paste, that shrank 7.0 per cent in drying, and 8.0 per cent additional when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 61 pounds to the square inch. It burned to a hard, compact body. Incipient vitrification occurred at cone 4 (2,210 degrees F.), complete at cone 9 (2,390 degrees F.).

This is a fair grade of buff-burning, terra cotta clay.

OHIO COUNTY.

The two following Ohio county clays were not turned over to the writer to be tested, but the analysis and remarks by the Survey Chemist, J. S. McHargue, are given below.

CHEMIST'S No. 3171. Location of clay: on the Power's place, Narrows, Ky. On the branch of I. C. R. R. between Owensboro and Horse Branch, Ky. Sent by Lyman B. Rosenfield, Henderson, Ky.

A very large sample of rather large, medium and fine red clay material, containing some roots and a few pieces of unweathered shale. Fusible in blow-pipe flame.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° F.	3.40
Combined water	9.51
Silica	51.84
Alumina	22.80
Ferric oxide	7.36
Ferrous oxide	0.58
Calcium oxide	tr.
Magnesium	1.48
Sulphur trioxide	none
Phosphates	tr.
Potassium oxide	2.48
Sodium oxide	0.50
Titanium dioxide	0.50
Total	100.45
Ratio of Iron and Alumina to Silica	1.68

Should be good for terra cotta, a fine clay for building brick.

CHEMIST'S No. 3172. Location of clay: on the Power's place, Narrows, Ky. On the I. C. R. R. branch between Owensboro and Horse Branch, Ohio county, Ky. Sent by Lyman B. Rosenfield, Henderson, Ky.

A large sample of gray clay containing unweathered shale and fine clay material. A fair looking specimen of clay. Slightly fusible in blow-pipe flame. Burns white.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	1.53
Combined water	6.31
Silica	64.60
Alumina	19.70
Ferric oxide	1.84
Ferrous oxide	0.50
Calcium oxide	tr.
Magnesium oxide	1.12
Sulphur trioxide	tr.
Phosphates	none
Potassium oxide	2.52
Sodium oxide	0.45
Titanium dioxide	0.90
Total	99.47
Ratio of Iron and Alumina to Silica	2.92

The composition is right for a Portland cement clay.

CLAY No. 134. (Chemist's No. 3178.) White clay from Power's place on I. C. R. R., between Owensboro and Horse Branch, Ohio county, Ky. Sent by Lyman B. Rosenfield, Henderson, Ky.

Sample consisted of several rather large lumps of gray clay coated in seams with iron oxide. Slightly fusible in blow-pipe flame. Not an average sample.

Analysis of Air-dried Sample:

	Per cent.
Moisture at 100° C.	2.20
Combined water	6.09
Silica	61.44
Alumina	21.44
Ferric oxide	2.16
Ferrous oxide	0.57
Calcium oxide	1.20
Magnesium oxide	1.01
Sodium oxide	0.82
Potassium oxide	2.83
Titanium dioxide	0.50
Sulphur trioxide	tr.
Phosphorus	none
Total	100.26
Ratio of Iron and Alumina to Silica	2.51

The sample of this clay gave the following characteristics: Color, bluish-gray; burned bright cream-yellow at cone 1 (2,102 degrees F.), changing to dark gray at higher temperatures. Taste, fat, slightly gritty. Texture, hard, fine-grained. When ground to 20-mesh and mixed with 22.5 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying, and 7.5 per cent additional when vitrified, giving a total shrinkage of 12.5 per cent. The air-dried mud showed a tensile strength of 76 pounds to the square inch, as the average of fourteen tests, with a maximum strength of 110 pounds. It burned to a hard, compact body free from warping. Complete vitrification occurred at cone 9 (2,390 degrees F.). This clay will make a good grade of terra cotta, pressed brick, etc.

CLAY No. 80. (Chemist's No. 3124.) This clay is from Board's Switch, about three miles southeast of Fordsville, Ohio county, Ky. The clay is about six feet above the railroad and lies above the Mitchell Limestone.

A sample of this clay gave the following characteristics: Color, red to yellow; reddish-yellow when mixed; dark red when burned. Taste, fat, gritty, and quite sour. Texture, soft coarse and fine-grained, containing some roots and gravel. When ground to 20-mesh and mixed with 37.0 per cent of water, it made a plastic paste, that stood a fair rate of drying, and that shrank 10.0 per cent in drying and a like amount when vitrified, giving a total shrinkage of 20.0 per cent. The air-dried mud showed a tensile strength of 161 pounds to the square inch (only one test). It burned to a hard, compact body, nearly vitrified at cone 1 (2,102 degrees F.), without much farther change towards viscosity at cone 6 (2,282 degrees F.). This is a common-brick and drain-tile clay.

The analysis of this clay follows:

	Per cent.
Moisture at 100° C.	3.75
Combined water	9.32
Silica	52.10
Alumina	22.48
Ferric oxide	6.88
Ferrous oxide	0.65
Calcium oxide	tr.
Magnesium oxide	1.45

	Per cent.
Sulphur trioxide	none
Phosphorus pentoxide	none
Potassium oxide	3.04
Sodium oxide	0.01
Titanium dioxide	0.62
Total	100.30
Ratio of Iron and Alumina to Silica	1.73
Rational analysis:	
Quartz	34.69
Feldspar	11.88
Clay substance	40.36
Moisture and combined water	3.07
Total	100.00

POWELL COUNTY.

CLAY NO. 67. (See Clay No. 146, Clark county.) The A. H. Anderson Place. The clay exposure under consideration is on the Indian Fields and Clay City Road, at the crossing of the Virden and Kiddville road, two miles southeast of Indian Fields, Clark County, Ky., about three hundred yards west of the L. & E. R. R.

Here there is a long gully which exposes the entire deposit of greenish, plastic clay. The deposit is quite an extensive one vertically and is found exposed over an area of from fifty to seventy-five acres. The clay is Crab Orchard and is interlaid with strata of massive brown limestone. It is well suited for shipping or for being worked on the ground. Lulbegrud creek flows along about thirty feet below the deposit. The following is a section of the exposure:

		Ft.	In.
1.	Soil and vegetation	2	
2.	Greenish, plastic clay	10	
3.	Brown limestone layer	10	
4.	Greenish, plastic clay	11	6
5.	Brown limestone layer	4	8
6.	Greenish, plastic clay	15	
7.	Sand from Lulbegrud Creek	Unconformity*	

*Ky. Geol. Surv., Bull. No. 6, p. 68.

A sample of this clay gave the following characteristic: Color, green; burned to a dark brown, almost black when fused. Taste, fat, free from grit. Texture, soft, fine-grained. When ground to 30-mesh and mixed with 26.0 per cent of water, it made a very plastic paste, that stood rapid drying, and that shrank 9.0 per cent in drying. The air-dried mud showed a tensile strength of 130 pounds to the square inch, as the average of three tests, with a maximum strength of 153.8 pounds. The clay reached viscosity at cone 6 (2,282 degrees F.). This is a low-grade clay that will make common brick.

CLAY No. 60. The Virden Exposure. In the first cut east from Virden, on the L. & E. R. R., Powell County, Ky., there is an exposure of Crab Orchard Shale. This shale, where exposed, has weathered to a greenish, plastic clay.

The land on either side of the railroad here is owned by Mr. A. H. Anderson. In the cut there is about four feet of Crab Orchard Shale at the bottom, overlaid by Corniferous Limestone, which is itself overlaid by Ohio Black Shale. This shale and clay are exposed over the lands on both sides of the railroad, covering an area of about one hundred acres. The strata of Corniferous Limestone range from five to nine feet in thickness. Following is an average section of the exposures here:

1.	Ohio black shale	20 ft.
2.	Corniferous limestone	5 to 9 ft.
3.	Greenish shale (Silurian)	4 to 7 ft.
4.	Covered.	

Following is the analysis of this clayey shale, made for the survey by the State Agricultural Experiment Station:

	Per cent.
Hygroscopic moisture	1.99
Combined water and volatile matter	19.26
Silica	37.30
Alumina	15.63
Ferric oxide	2.37(?)
Lime	10.59
Magnesia	2.22
Potash	3.56
Soda	0.33

	Per cent.
Titanium dioxide	0.50
Sulphur trioxide	0.12(?)
Phosphorus pentoxide	0.26
Iron bisulphide (FeS_2)	4.65(?)
Total	98.78

The total sulphur, calculated as SO_3, is 6.31 per cent. Total iron, calculated as FeO_3, is 5.47 per cent. The greater part of the sulphur is in the FeS_2, but some of it is evidently in the form of sulphate. (*)

A sample of this clay gave the following characteristics: Color, green, both wet and dry; burned to a dark brown. Taste, fairly fat, and very little grit. Texture, soft, shaly, coarse-grained. When ground to 30-mesh and mixed with 22.0 per cent of water, it makes a moderately plastic paste, that required slow drying, and that shrank 5.0 per cent in drying. The air-dried mud showed a tensile strength of 95 pounds to the square inch, the same strength being given by each of three tests. The clay was completely fused at cone 4 (2210° F.). This is an exceedingly low-grade clay.

CLAY NO. 69. The J. M. Kennon Place. This place is on the Clay City and Hardwick's Creek Road, one mile from Clay City, Powell County, Ky.

The clay examined on this farm is in a low, level area which was once covered by Red River. The clay is plainly fluviatile in origin and is of a light brown color. It is reported as a good brick clay, having been used for this purpose by a local company. The exposure presents about three feet of the upper portion of the deposit. The entire thickness is about six feet. Following is the section of exposure:

1.	Sandy soil	2 ft.
2.	Light, brown clay	6 ft.
3.	Covered.(†)	

A sample of this clay gave the following characteristics: Color when mixed, brownish-gray—quite dark;

*Ky. Geol. Surv., Bull. No. 6, p. 70.
†Ky. Geol. Curv., Bull. No. 6, p. 71.

when burned to cone 1 (2102° F.), the color was bright red, very thickly speckled with white particles; became dark red at higher temperatures and less speckled. Taste, fairly fat, sour, and free from grit. Texture, soft, soil-like, coarse-grained. When ground to 20 mesh and mixed with 35.0 per cent of water, it made a plastic paste, that required slow drying and that shrank 6.0 per cent in drying and 12.0 per cent additional when vitrified, giving a total shrinkage of 18.0 per cent. The air-dried mud showed a tensile strength of 101 pounds to the square inch, as the average of five tests, with a maximum strength of 106 pounds. Incipient vitrification occurred at cone 1 (2102° F.), complete at cone 6 (2282° F.). This is a low-grade clay that is of little value except for a medium grade of common brick.

CLAY NO. 63. The John Wasson Place. The farm of Mr. John Wasson is on the Rosslyn and Cat Creek Road four miles south of Rosslyn, Powell County, Ky.

The vicinity is one of rugged topography and the highest ridges are capped with Conglomerate Sandstone, the basal formation of the Coal Measures.

Around a valley on the flanks of two ridges on the named farm, there are exposures of a fire-clay deposit at the base of this Conglomerate Sandstone. The exact thickness was not determined, only three feet of the deposit being uncovered at any one place, but supposed authorities claimed that a prospect pit was once dug through it showing it to be about seven feet thick. The prospect pit was dug for iron ore. A light, bluish plastic clay, often used as a substitute for whitewash, is common below the fire clay in thin layers. It is eroded and redeposited particles of the fire clay.

Following is a section of the exposure:

1.	Soil	2 ft.
2.	Fire clay	3 ft.
3.	Covered.(*)	

A sample of this clay gave the following characteristics: Color, bluish-gray—very dark; burned nearly white with yellow tint. Taste, lean, and very hard. Texture, hard, fine-grained, slaty. When ground to 30-mesh

*Ky. Geol. Surv., Bull. No. 6, p. 72.

and mixed with 16.0 per cent of water, it made an exceedingly lean paste, almost wholly wanting in plasticity, and having a tensile strength too low to test. The paste shrank almost none in drying and only 7.0 per cent in burning to cone 11 (2462° F.). It burned to a crumbly, sandy body. This is a good grade of fire sand.

CLAY NO. 54. The Edmund Rose Place. The land under consideration is on the Clay City and Stanton Road one mile east of Clay City, Powell County, Ky.

The clay deposit here rests on Ohio Black Shale at the very top. The clay is of a shaly character, bluish in color and contains a layer of iron oxide near the center. The entire deposit is about fourteen feet thick. At other points around the same elevations over a considerable area, this clay is exposed. The iron layer is very persistent. The following is a section of average exposure:

1.	Shaly plastic clay	5½	ft.
2.	Layer of iron oxide	4	in.
3.	Shaly, plastic clay	8	ft.
4.	Ohio black shale	95	ft.(*)

A sample of this clay gave the following characteristics: Color, gray and brown; when mixed, the color was brownish-gray; it burned to a dark reddish-brown. Taste, fat, and free from grit. Texture, soft, fine-grained, shaly. When ground to 30-mesh and mixed with 25.0 of water, it made a very plastic paste, that stood rapid drying, and that shrank 3.0 per cent in drying, and a like amount when vitrified, giving a total shrinkage of 6.0 per cent. The air-dried mud showed a tensile strength of 73 pounds to the square inch, as the average of five tests, with a maximum strength of 82.5 pounds. The clay burned to a hard, compact body, fully vitrified at cone 7 (2318° F.).

This clay would make a fair grade of paving brick, but the mud has a rather low tensile strength.

CLAY NO. 43. Plastic tile clay from L. & E. R. R. cut, fifty yards west of station at Stanton, Powell County, Ky. Hamilton clay.

A sample of this clay gave the following characteristics: Color, pale greenish-yellow with bright yellow

*Ky. Geol. Surv., Bull No. 6, p. 71.

streaks; when mixed, the color was greenish-yellow; it burned to a dark brown with a reddish tint. Taste, lean, and quite gritty. Texture, soft, porous, coarse and fine-grained. When ground to 30-mesh and mixed with 25.0 per cent of water, it made a mildly plastic paste that stood rapid drying, and that shrank 4.0 per cent in drying and 6.0 per cent additional when vitrified, giving a total shrinkage of 10.0 per cent. Complete vitrification occurred at cone 7 (2318° F.), the clay burning to a hard, compact body without warping when in thin slabs.

The air-dried mud showed a tensile strength of 102 pounds to the square inch, with a maximum strength of 106.4 pounds. This clay will make dark red-burning, pressed brick, or tile.

CLAY No. 41. Filson Station. A dark, plastic clay occurs in the L. & E. R. R. cut, one mile east of Filson, Powell County, Ky. It is in the farm of Mr. Jesse Faulkner.

About seven feet of the deposit is exposed by a cut along the railroad. It is a dark, plastic clay of fluviatile origin and rests on the Waverly shale. The clay is free from gritty particles and is quite strong and fat. Following is a section of the exposure:

1.	Soil	1½ ft.
2.	Dark, plastic clay	7 ft.
3.	Waverly shale	Bottom of cut

Following is the analysis of this clay made for the survey by the Kentucky Experiment Station:

Sample, a light brown clay with a good many iron stains. Waverly formation (Linietta (?) Clay).

	Per cent.
Moisture	3.46
Combined water and volatile matter	6.36
Silica	64.54
Alumina	19.13
Ferric oxide	0.94
Lime	0.53
Magnesia	0.66
Potash	2.32
Soda	0.51
Titanium dioxide	0.95
Sulphur trioxide	tr.
Total	99.40(*)

*Ky. Geol. Surv., Bull. No. 6, p. 75.

A sample of this clay gave the following characteristics: Color, greenish-gray, containing yellow spots; mixed, the color was greenish-gray; burned to a grayish brown. Taste, fat and gritty. Texture, soft, fine-grained, compact and massive. When disintegrated by prolonged shaking in water, some clear, sharp quartz remained on the 100-mesh sieve.

When ground to 20-mesh and mixed with 27.0 per cent of water, it made a plastic paste, that stood rapid drying, and that shrank 7.0 per cent in drying, and 8.0 per cent more when vitrified, giving a total shrinkage of 15.0 per cent. The air-dried mud showed a tensile strength of 171 pounds to the square inch, as the average of five tests, with a maximum strength of 220.4 pounds. Incipient vitrification occurred at cone 4 (2210° F.), complete at cone 7 (2318° F.). The clay burned to a hard, compact body suited to the manufacture of stoneware, etc.

TAYLOR COUNTY.

CLAY No. 93. (Chemist's No. 3129). Clay one and a half miles southeast of Hibernia, Taylor County, Ky. Residual, St. Louis. The J. T. Purvis Place, on the south side of Campbellsville Road.

Average sample of a mixture of red, yellow and white clay. Plastic and fusible.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	2.00
Combined water	6.56
Silica	59.54
Alumina	18.16
Ferric oxide	6.40
Ferrous oxide	0.58
Calcium oxide	tr.
Magnesium oxide	1.68
Sulphur trioxide	none
Phosphates	none
Potassium oxide	3.40
Sodium oxide	0.55
Titanium dioxide	0.80
Total	99.67
Ratio of Iron and Alumina to Silica	2.36

A sample of this clay gave the following characteristics: Color, pinkish-red; burned dark red and shaded off into dark brown. Taste, fat and smooth. Texture, soft and fine grained. When ground to 20-mesh and mixed with 37.0 per cent of water, it made a plastic paste, that shrank 5.0 per cent in drying, and 7.0 per cent additional when vitrified, giving a total shrinkage of 12.0 per cent. The air-dried mud showed a tensile strength of 71.5 pounds to the square inch. Complete vitrification occurred below cone 1 (2102° F.), and partial viscosity at cone 6 (2282° F.). This is a common brick clay, or drain-tile clay.

UNION COUNTY.

CLAY No. 57. Henshaw Brick & Tile Co. This company is located at Henshaw, Union County, Ky. They use a dark siliceous soil, which burns to a bad brick because of calcium carbonate.

A sample of this clay gave the following characteristics: Color, dark, greenish-gray; burned to a reddish-yellow, and shaded on into dark red at higher temperatures. Taste, mildly fat, and very little grit. Texture, soft, fine and coarse-grained, soil, full of roots and fibers. When ground to 30-mesh and mixed with 35.0 per cent of water, it made a mildly plastic paste, that shrank 6.0 per cent in drying, and 11.0 per cent more when vitrified, giving a total shrinkage of 17.0 per cent. The air-dried mud showed a tensile strength of 79.8 pounds to the square inch, as the average of five tests, with a maximum strength of 85 pounds.

The clay was fully vitrified at cone 6 (2282° F.). It burned to a rather porous body. This is a low-grade clay, suited only to the manufacture of common brick and drain tile.

WOLFE COUNTY.

CLAY No. 58. J. B. Kash and J. W. Stamper exposures. Mr. Kash's farm is on the Hazel Green and Mt. Sterling Road, one mile west of Hazel Green, Wolfe County.

Mr. Stamper's farm joins Mr. Kash on the west. On Mr. Stamper's land, small, angular particles of flint

fire-clay can easily be traced around the high points. These hills are capped with shales of the Coal Measures, and it is near the summit that the fire-clay appears. This deposit was traced on to Mr. Kash's land, where it is at a much lower elevation because of an anticlinal dip.

No accurate section can be given of this deposit until a prospect pit has been dug into it. Because of the scouting nature of the field work, this was not done by the survey. The outcroppings indicate a deposit of workable thickness.(*)

A sample of this clay gave the following characteristics: Color, slate-like dark bluish-gray; burned pure white. Taste, exceedingly hard and lean. Texture, flinty, hard. When ground to 30-mesh and mixed with 15.0 per cent of water, it made a paste almost wholly wanting in plasticity, that shrank practically none in drying, and 6.0 per cent in burning to cone 7 (2318° F.). The air-dried mud showed a tensile strength of only 15 pounds to the square inch. It burned to a crumbly, grannular body at cone 11 (2462° F.), at which point no indication of vitrification could be detected.

This is a high-grade flint fire-clay.

CLAY No. 52. The S. W. Perkins place. This land is south of the Hazel Green and Mt. Sterling Road, one and a half miles west of Hazel Green, Wolfe County, Ky. Here there is a long, level bottom east and adjacent to Red River. Below this low, marshy bottom land there is a bluish plastic clay which becomes much whiter when dried and is probably a valuable clay for brick, tile, sewers, etc. The clay is fluviatile, having been deposited by Red River. It is about six feet thick, and shows over an area of about thirty acres. Very thin, damp soil covers the clay, as shown by the following section:

1.	Soil	½ ft.
2.	Plastic clay	6 ft.
3.	Shale.	

This clay, mixed with a proper percentage of calcium carbonate, might make an excellent cement. (†)

*Ky. Geol. Surv., Bull. No. 6, p. 78.
†Ky. Geol. Surv., Bull. No. 6, p. 79.

A sample of this clay from the H. H. Stidam and S. W. Perkins places gave the following characteristics: Color, yellowish-green, both wet and dry; burned, the color was red up to cone 6 (2282° F.), but became brown at higher temperatures. Taste, lean and gritty. Texture, soft and crumbly, coarse-grained. When ground to 30-mesh and mixed with 18.0 per cent water, it made a rather lean paste, that required slow drying, and that shrank 5.0 per cent in drying and an additional 3.0 per cent when vitrified, giving a total shrinkage of 8.0 per cent. The air-dried mud showed a tensile strength of 52.5 pounds to the square inch, as the average of three tests, with a maximum strength of 58 pounds.

The clay burned to a porous body not more than slightly vitrified at cone 9 (2390° F.); there was no warping when thin pieces were burned.

This is a fair grade of red-burning, semi-refractory clay.

CLAY NO. 50. The J. Taylor Day place. The land owned by Mr. J. Taylor Day is one-fourth mile west of Torrent, Wolfe, County, Ky. Geological position, Pennington.

A sample of this clay gave the following characteristics: Color, yellow and gray; when ground and mixed the color was gray with a slight yellowish tint; burned to a yellowish-red up to cone 6 (2282° F.), changing to a reddish-gray, then to a gray, with increased temperature. Taste, lean and gritty. Texture, shaly, hard, coarse-grained. When ground to 30-mesh and mixed with 20.0 per cent of water, it made a lean paste, lacking in plasticity, that stood rapid drying, and that shrank 7.0 in drying and none in burning, giving a total shrinkage of 7.0 per cent. The air-dried mud showed a tensile strength of 24.7 pounds to the square inch, as the average of eight tests, with a maximum strength of 32.3 pounds. Incipient vitrification occurred at cone 7 (2318° F.). This is a refractory fire-clay of fair quality.

CLAY NO. 21. The N. Fulks place. Land belonging to Mr. Fulks lies east and adjacent to the village of Glencairn, Wolfe County.

On the side of a hill above the first east cut in the Waverly Shale for the L. & E. R. R., there is an exposure of drab, plastic clay. This clay deposit is not in work-

able quantity, being a product of redeposition from argillaceous shales and refractory clay above. Above this plastic clay about thirty feet there is a stratum of fire-clay about one and a half feet thick. This is at the junction of the Waverly and St. Louis limestone.

The following section includes both clays, neither of which is of more than geological interest probably:

1.	St. Louis limestone	40	ft.
2.	Refractory clay	1½	ft.
3.	Covered	20	ft.
4.	Drab, plastic clay	2	ft.
5.	Waverly shale, to bottom of cut	23	ft.(*)

A sample of this argillaceous shale gave the following characteristics: Color, green, both wet and dry; burned to cone 1 (2102° F.), the color was dark red, becoming dark brown at higher temperatures. Taste, lean and gritty. Texture, shaly, soft, and fine-grained. When disintegrated by prolonged shaking in water practically no detritus was caught on the 100-mesh sieve.

When ground to 20-mesh and mixed with 24.0 per cent of water, it made a lean paste, that stood moderately rapid drying, and that shrank 5.0 per cent in drying and 4.0 per cent more in burning, giving a total shrinkage of 9.0 per cent. The air-dried mud showed a tensile strength of 47.4 pounds to the square inch, as the average of six tests, with a maximum strength of 52.6 pounds. Incipient vitrification occurred at cone 1 (2102° F.), complete at cone 5 (2246° F.). This is a low-grade clay, that may do for common brick.

CLAY NO. 99. (Chemist's No. 3125). The O. W. McNabb place. This place is on the Hazel Green and Mt. Sterling Road, about one mile northwest of Hazel Green, Wolfe County, Ky. Here is a light, plastic clay occurring in the coal measures.

Average sample of white clay containing small splotches of iron. Plastic and non-fusible in blow-pipe flame.

*Ky. Geol. Surv., Bull. No. 6, p. 76.

Analysis of Air-Dried Sample.

	Per cent.
Moisture at 100° C.	0.70
Combined water	3.46
Silica	76.90
Alumina	13.03
Ferric oxide	1.36
Ferrous oxide	0.42
Calcium oxide	none
Magnesium oxide	0.72
Sulphur trioxide	none
Phosphates	none
Potassium oxide	2.30
Sodium oxide	0.47
Titanium dioxide	0.87
Carbonates	none
Total	100.23
Ratio of Iron and Alumina to Silica	4.80

A sample of this clay gave the following characteristics: Color, greenish-white; burned to a pink, changing to a green at cone 9 (2390° F.). Taste, fat, sour, and some grit. When ground to 20-mesh and mixed with 24.0 per cent of water, it made a fairly plastic paste, that shrank 5.0 per cent in drying, and an equal amount in burning, giving a total shrinkage of 10.0 per cent. The air-dried mud showed a tensile strength of 29.5 pounds to the square inch. Incipient vitrification occurred at cone 4 (2210° F.), complete at cone 8 (2354° F.).

This clay will make a satisfactory pressed brick.

REPORT ON THE COALS OF THE HEADWATERS OF LICKING RIVER, MAGOFFIN COUNTY.

BY

JAMES M. HODGE.

This report gives the results of a recent investigation of the coal field drained by Licking river from the mouth of Oakley creek, about five miles south of Salyersville, the county seat of Magoffin County, to the head of the river. This area is about twelve miles long and nine in width at its northern end narrowing to four miles at its southern end.

The accompanying map shows the position of the principal coal openings, and the longitudinal section shows the vertical order of the coal beds with relation to the main drainage. This section shows the coal beds very nearly in their actual position where they are above drainage on the Licking river, and their probable position below drainage. Their extension of all beds shown on to Beaver creek waters will doubtless require much modification as data, now lacking, is supplied.

Like most of Eastern Kentucky, the valleys are all narrow, generally proportioned to the size of the streams, the hills steep and terminating in narrow ridges. These serrated ridges are some three hundred feet high along the river, but increase towards the heads of streams, more especially southward, where they reach a height of about 1,700 feet above tide, and six hundred feet above the river near its main head.

The height of the Upper Licking valley varies little from that of the corresponding part of the Kentucky river, but, farther down stream, owing to greater volume of water to effect erosion, and possibly also to less resistance of the conglomerate measures forming the northeast edge of the geologic basin, the Kentucky river is several hundred feet lower than the Licking.

For the same reasons the same is true as regards the height of Big Sandy river (and principal branches) relative to the Licking, but the difference is more marked

there, as the head of the latter abuts directly against the former. These differences in altitude make railroad passage from the Licking river to the Kentucky river troublesome, and to the Big Sandy river almost impracticable, even though remarkably low gaps assist, as on Brushy creek, and at the head of Grassy creek where they are only 175 feet higher than their mouths.

The fall of the Licking from a mile below its extreme head to Oakley creek is very light, being, in a distance along the river of over twenty miles, but about 200 feet, an average of less than ten feet per mile. Branches of the river also have but little fall.

The difference in altitude of the highest point of the region under review, say 1,700 feet above sea, and of the lowest, the mouth of Oakley creek, 860 feet above sea, is about 840 feet, but owing to rise of strata toward surrounding ridges the vertical range of the strata is limited to a thickness of some 500 feet.

In the following description of these strata the nomenclature of the several principal coal beds followed is that adopted in Bulletin No. 11 of the Kentucky Geological Survey. The Hyden, or Fire clay coal bed, with its unique parting gives means for positive correlation of that bed here and in adjoining fields, and also serves as a reliable guide in correlating other beds.

The three most prominenet coal beds of the region and intervals between them are as follows:

Flag coal
  Interval ....80 to 90 feet
Hazard coal
  Interval ....60 to 90 feet
Haddix coal
  Interval ....30 to 60 feet
Fire clay coal
  Interval ....50 to 80 feet
No. 3 coal.

The correlation of all but the No. 3 coal, the lowest of these beds, with the same on Kentucky river is given with confidence, though the intervals are much reduced below those obtained on that river.

The lowest coal is supposed to be No. 3, because of its similarity to the bed in the counties to the northeast.

The adjacent strata tend also to confirm this view; but, if such is the case, there is an unexpectedly large decrease of interval from the Fire clay coal of the Kentucky river to the Licking, and but little thence northeast. The assumption that it is No. 3 in the following pages must therefore be regarded as tentative. A still lower coal showing at the mouth of Oakley creek near the bed of the river and about 120 feet below the Fire clay coal may possibly be the No. 3, but as it goes under drainage up the river its bed section cannot be given.

The 500 feet of strata above drainage range from 125 feet below the Fire clay coal at the mouth of Oakley creek to about 175 feet above the Hazard coal at the head of the river.

Their general dip along the river is up stream from the mouth of Oakley to the vicinity of Bullmire creek at a rate of some fifteen feet per mile, while going up the river from the mouth of Gun creek to the mouth of Bullmire (more nearly in the direction of the dip), the fall is about 30 feet per mile. The dip reverses there, and rises at a slightly faster rate to Bull creek; from the mouth of Bull creek up to the mouth of Grassy creek they rise about with the river, but rise somewhat faster from there to the head of the river. Up Grassy creek the strata rise rapidly.

Along the main river above the mouth of Grassy creek the rate of rise is considerably less than up Grassy, but it is known to continue to within a half mile of the head of the river, and from this it is inferred that the rise continues beyond the gap at the head of Grassy creek. Data are lacking for any attempt at accurate connection with the coals of Beaver creek, but the section is continued to show, in a general way, what this connection may be.

Up branch streams on the east side of the Licking river there is a rise of strata nearly conforming to the ascent of the valleys, until their heads are closely approached, and this presumably continues to and beyond the dividing ridge.

On tributaries from the west up to Bullmire creek the strata lie so nearly level that their dip has not been determined. Above Bullmire there is a slight rise up the streams.

Nothing is known in this field of any coals higher than the Flag, except that their areas must be too small for working. Nor does the Flag bed give promise of value, its two known openings giving only about three feet of coal, in one case, at least, ruined by partings. Its bench, however, is a conspicuous feature of the hillsides in numerous places.

The chief bench throughout all except the extreme lower end of the region is that of the Hazard coal. By it the location of the bed, within narrow limits, can often be defined with a tolerable degree of certainty when other means are lacking. This coal, too, is by far the most important of the region, though it has been developed as a thick coal mainly near the head of the river, with an area of some 25 square miles only, and within this area probably from one-half to two-thirds of the area underlaid by the coal has been eroded. On the other hand loss by erosion may be largely offset by available coal beyond the limit of the Licking watershed, thick coal having been reported across the divide on Quicksand creek, and (more definitely) eastward on Middle creek.

Within this limited area the Hazard seam has a thickness of coal, as now developed, of from five to eight and one-half feet, an inch or two short of five feet being most common; where of this or less thickness partings are absent or nearly so. Usually a rider of coal a foot thick, more or less, lies in clay shale about five feet above the main bed. This shale makes a bad roof for the coal, but occasionally a hard stratum near the coal affords better mining conditions.

Elsewhere in this field, except on Oakley and Bullmire creeks, this coal has been found rather thin and hurt by partings, though some partial exposures are rather promising.

The coal of this bed consists of common block and splint in varying proportions, the latter generally occupying most of the lower half of the bed. Both, as a rule, appear to be good, though the splint is of a somewhat dull appearance. Thin seams of an inch or two look much like bone coal, but several tests in fires proved them not quite such, though evidently high in ash. Wherever

seen in stock or burning in grates no fault could be found with the coal of the whole bed.

Analyses of samples recently obtained are not at hand, but one of a sample by Prof. Crandall, high in ash as compared with coals farther south, is given on a succeeding page.

The Haddix coal is opened near the mouth of Salt Lick creek, 28 inches thick without parting, containing cannel coal, and at the head of that creek (with doubtful correlation) 34 inches coal with cannel slate roof. Elsewhere it has only been found as a thin bed, but its known openings are very few.

The Fire clay coal bed has been mined for local use to a considerable extent in the hill opposite the mouth of Oakley creek, and on that stream and the river above it up to the mouth of Gun creek, frequent openings into the bed have been made. With few exceptions they give less than three feet of coal, and with the flint fire clay parting everywhere present. Mr. Patrick's opening on Gun creek with over four feet of coal and 18 inches of parting appears to be of this bed.

Up the river from Gun creek the bed becomes thinner. At Swampton it shows 10 inches of coal, with parting 1 inch. Beyond there it lies near river level to the mouth of Grassy creek, rising thence well above drainage, but without yet developing workable coal. An opening showing 40 inches of coal with 4 inches parting across the Beaver divide, near the head of Salt Lick creek, should lead to its development on the extreme head of the river.

The No. 3 coal, which on the Kentucky river is some 200 feet below the Fire clay coal, and in the northeastern counties is given at about 40 feet, appears to be on Gun creek 80 feet and possibly on Grassy creek 60 to 80 feet below that bed.

Its outcrop is limited in the lower part of this region to Oakley creek below Open Fork, the river valley up to Puncheon Camp creek, and the streams east of the river up to that creek, and in the upper part of the region, perhaps to the heads of Salt Lick and Grassy creeks and of the main river. The numerous openings made into the bed on Gun and Puncheon Camp creeks nowhere

show so much as 3 feet of coal, and all have a parting, but it is not unlikely that a 4-foot bed found on Grassy creek is of this bed, and that it continues at about creek level a mile or more up that valley, as well as along the river above Grassy creek. This deserves thorough investigation, for if present of minable thickness it will add immensely to the importance of the whole region thereabout. Its location on the longitudinal section, 50 feet below drainage, is only tentative.

No. 2 coal is nowhere very attractive, but No. 1 coal, 200 feet below the No. 3 on Kentucky river and little less below it to the northeast, should be found to lie 150 to 200 feet under the river between Oakley and Gun creeks. The excellent showing 3 to 5 feet of coal in a seam at approximately the same horizon on Beaver creek, and elsewhere, should lead to its investigation by the drill on those creeks.

All of the above coals, so far as known, give satisfactory service for domestic use, are doubtless good steam coals, dry burning and non-coking. Evidence of sulphur is extremely rare, and ash, except in a few cases, seems to be not high.

Carbonate iron ore such as was formerly worked quite extensively in the northeastern counties, was found at several places, noted in the detailed description following. It appeared to be too thin for working, but further investigation of it is desirable.

In the following detailed description of openings visited elevations are given as above tide water, based on those obtained from a railroad survey giving heights at the forks of Oakley and mouth of Gun creek, another survey, assumed to agree with the above, giving height of the river a half mile below Grassy creek and a U. S. Geological Survey elevation on the river near its head. Other river elevations were obtained by interpolation, and from all these data heights of openings were deduced by barometric readings, and are given as above tide, generally sufficiently accurate for present purposes.

Distances are given as estimated, being intended merely to serve for guidance.

Beginning with the lowest tributary each stream on which coal was seen is followed up in ascending order,

left the right being used in description according as the object is on the left or right when facing up stream.

OAKLEY CREEK.

ELEVATION AT MOUTH, 860.

William Harris has a 10-yard entry on the left, and left of the road, 3/4 mile up the creek in which the fire-clay coal has a somewhat variable section taken as:

Fire Clay Coal.

S. S.	8 ft.	
Coal	11″	
Flint fire clay	5″	Elevation 955.
Coal	22″	

OPEN FORK OF OAKLEY.

ELEVATION AT MOUTH, 865.

Calloway Montgomery's opening on the left, 1/4 mile up, gives the same bed:

Fire Clay Coal.

S. S.	10 ft.	
Coal	11″	
Flint fire clay	3″	
Coal	11″	Elevation 935.
Soft shale	3″	
Coal	10″	

At the creek level, a mile up, under 15 feet of sandstone, at a natural exposure the three seams of the preceding vein contain but 26 inches of coal and the lower parting is 12 inches thick. The flint fire-clay is black, and looks almost like shelly cannel coal when freshly broken.

Directly under the bed is 5 feet of shale, containing calcareous concretions, and 8 inches of coal is under that: Elevation, 890.

Two and one-half miles up the main creek, 1/4 mile up a left branch, Asbury Salyers has a good showing of the fire-clay coal, but the lower part is in the branch. It has a sandstone roof, 14 inches of coal to the flint fire-clay and 2 to 2 1/2 feet of coal below. Elevation, 930.

On the left, 3 miles up a natural exposure shows by the road only 14 inches of coal with 3 inches of black flint fire clay parting: Elevation, 890.

BEE TREE FORK OF OAKLEY.—On the right, 3 miles up. Elevation of mouth, 915.

On the left at the mouth, Isaac Montgomery has an entry, now abandoned, of which Prof. Crandall gives, in Bulletin No. 10, the following section:

Hazard Coal.

Shale.		
Cannel slate	4"	
Coal	35"	Elevation 1040.
Shale	7"	
Coal	20"	

This is the Hazard bed, on a good bench, plainly visible on the neighboring hillside. A minor bench and spring at 975 mark the location of another coal opened at the head of Oakley. Almost under the entry the fireclay bed is exposed beside the road up Bee Tree with elevation 920. This gives an excellent opportunity for getting the interval (120 feet) between that bed and the Hazard.

On the left of the fork, a mile up and 100 feet above it, Wesley Rewe has an entry into the Hazard bed, which is about four feet thick. Elevation, 1,085.

On the right, $1\frac{1}{4}$ miles up, $\frac{1}{8}$ mile up a right branch an entry gives at its mouth the following section:

Hazard Coal.

S. S.	18"	
Coal	30"	
Shale	8"	Elevation 1070.
Coal	9"	

The bottom 3" of this coal was in water and not seen.

On the left at the forks of Bee Tree fork, $1\frac{1}{2}$ miles up and two feet above it an entry, now fallen in, on the same bed, the Hazard gives:

Hazard Coal.

S. S.		
Shale	5 ft.	
Coal	24"+	Elevation 1055.
Shale	12"	
Coal (reported)	12"+	

Probably this is the same as Prof. Crandall gives with 28 and 10 inches coal and 7½ inches parting, though he gives a different roof.

The heights given of the four Hazard openings on this fork indicate an irregularity of the barometer rather than of dip of strata. It appears likely that those given for the mouth and head are nearest correct, making a slight rise in going up the fork.

RIGHT FORK.—Four miles up; elevation of mouth, 926. (By R. R. Survey.)

Ed. Marshall has an entry on a left branch ¼ mile up and ⅛ mile up it, 120 feet above the fork, with the following section:

Hazard Coal.

Shale		
Coal	40″	
Shale	9″	Elevation 1050.
Coal	9″	

At the forks a mile up, behind Joseph Watson's house, on the left, ⅛ mile up the branch, this section has been uncovered:

Hazard Coal.

Shaly S. S.	2 ft.	
Coal	4″	
Shale	9″	
Coal	18″	
Shale and S. S.	15 ft.	
Coal	33″	
Black clay	10″	Elevation 1090.
Coal	6″	

On the right of the same branch 1½ feet of coal 50 feet lower has a parting of shale (with coal) one foot thick and 5 feet of shale covering.

In view of the fact that the Hazard bed improves to good thickness near the forks of the creek it is especially regrettable that no openings could be learned of on the Left Fork. If the bed is found there up to the thickness of the Marshall coal, an important addition to the workable coal of the creek will be developed.

On the river opposite the mouth of Oakley creek, 130 feet above it, Joseph Arnett has an entry into the fire-clay bed from which (and connected entries) considerable coal for local use has been mined.

Following is a section taken at the mouth of the entry, a 6-inch "draw slate" found in the mine not appearing at the surface:

Fire Clay Coal.

S. S.	10 ft.	
Coal	10"	
Flint fire clay	4"	
Coal	21"	Elevation 980.
Clay or shale	18"	
Coal (reported)	14"	

Judge R. Salyers has an entry on the left ½ mile above the Arnett mine in which the thickness above the flint clay is 8 inches and below the flint clay 25 inches.

In both of the two preceding the foot of coal next under the flint clay is splinty. In all cases the coal of the whole bed appears to be excellent.

On the left, a mile above Oakley creek, Francis Gardiner has an abandoned entry with an exposure showing the beginning of a splitting of the fire-clay bed, which becomes more pronounced farther up the river. This section is:

S. S.	20 ft.	
Coal	4"	
Shale	3 ft.	
Coal	5"	
Shale	7 to 10"	Elevation 955.
Flint fire clay	3"	
Visible coal	12"	

The bottom coal may be two feet or more thick.

GUN CREEK.

ELEVATION OF MOUTH (BY R. R. SURVEY), 868.

In the river at the mouth of Gun creek a coal is mined for local use. 40 feet above it is another coal (probably No. 3), and 80 feet above that the fire-clay coal at an elevation of 980.

On the left, ½ mile up, at the big bend in the road, are two abandoned entries into what is regarded as the No. 3 coal. In conjunction with openings farther up the creek the dip toward the river is ascertained, and the consequent interval up to the fire-clay coal. The elevation of the entries is 905.

At ¾ mile up the creek, ⅛ mile up a left branch, the same bed has, in a 3-yard entry with sandstone roof, 26 inches of coal with 4 inches of parting.

At Fred Patrick's, one mile up and ⅛ mile up a hollow on the right, 125 feet above the creek, a 7-yard entry gives the following section, the bottom 8 inches, being in water, and somewhat uncertain:

S. S.	5 ft.	
Shale	6"	
Coal	22"	Elevation 1020.
Shale	18"	
Coal	29"+	

This appears to be a little too high for the fire-clay bed, and may be the Haddix.

BILL MAY BRANCH OF GUN CREEK.—On the left, 1½ miles up.

Three openings into the No. 3 bed on the first half mile of this branch give about 2½ feet of coal each. The bed rises from elevation 940 at the mouth of the branch to 960 a half mile up it.

At Marshall's, at the forks, 2 miles up, a 10-yard entry on the right, 40 feet above the creek, gives the following section:

No. 3 Coal.

Shale	7 ft.	
Coal	6"	
Shale	2"	Elevation 985.
Coal	24"	

Other openings reported on the forks above Mrs. Marshall's, with coal about the same thickness, were not visited.

ANDREW HOWARD BRANCH.

On the right, ½ mile above Gun creek. Elevation of mouth, 870.

At Andrew Howard's, on the right, ¼ mile up the branch, an entry with mouth filled up gave:

Fire Clay Coal.

Shaly S. S.	24"	
Black and cannel slate	12"	
Impure flint clay	4"	Elevation 940.
Coal	24 to 36"	

The upper seam (and elswhere the lower seam) of this coal is sometimes wanting, but this is the only known instance of its replacement by black slate. A case on Beaver creek has been reported of the absence of all coal from the bed, the flint fire-clay alone remaining to represent it.

HIGGINS BRANCH.

On the left, one mile above Gun creek. Elevation of mouth, 875.

On the left, ½ mile up the branch, Branch Higgins' 10-yard entry has the following section:

No. 3 Coal.

Shale	8 ft.
Black slate	6"
Coal	13"
Clay	6"
Coal	16"

Elevation, 900.

From the mouth of Higgins' branch to Henry Patton's house, ¼ mile up the river, the following section was obtained:

Soft S. S.	15 ft.	
Covered	60 ft.	
Coal	24"	
Covered	5 ft.	
Thin iron ore		
S. S.	20 ft.	
Shale	6"	
Coal	6"	
Flint fire clay	1"	Fire clay coal.
Coal	4"	Elevation 945.

Shale and clay	5 ft.
Coal	24"
Shale and thin S. S.	8 ft.
Coal	9"
Fire clay	24"
Shale	8 ft.
Coal	6"
Fire clay.	
Shale to river	40 ft.

The thick shale at the base is abundantly supplied with thin seams of limestone, small calcareous concretions in layers and some large lime boulders; by the road just above the Patton house it appears to be in part replaced by massive sandstone.

The two sandstones over the fire-clay coal are peculiar in having there nearly vertical seams an inch or two wide running in various directions, and filled with a darker and harder sandstone. In weathering the filling is left jutting somewhat above the softer sandstone enclosing it.

HALF-MOUNTAIN CREEK.

ELEVATION OF MOUTH, 890.

Asbury Stacy, ½ mile up the creek, has a 20-yard entry, ¼ mile up a right branch and 5 feet above it, with the following section:

Fire Clay Coal.

S. S.	2 ft.	
Shale	8 ft.	
Coal	15"	
Flint fire clay	3"	Elevation 930.
Coal	16"	

The only other openings heard of on this creek are near the head of Equal Fork (a fork on the right 4 miles from the river). A mile up Equal Fork, it divides into three forks. At their junction a thin splint coal lies in the stream, and follows the bed of the left one of the three forks for ¼ mile. At this point, some 30 feet above the splint coal, Thomas Conley has an opening into what is probably the Hazard bed. Milburn Conley has openings up the other two forks the same distance.

The three sections are given below:

Left Fork.

Shale	4 ft.	
Soft Coal	18"	
Mud	2"	Elevation 1015.
Soft coal	20"	

Middle Fork.

Shaly S. S.	4 ft.	
Coal	17"	
Shale	1"	
Coal	14"	Elevation 1015.
Shale	2"	
Coal	4"	

Right Fork.

Shaly S. S.	3 ft.	
Splint coal	27"	
Shale	1"	Elevation 1000.
Splint coal	5"	

The proximity of the left fork of the main creek to the thick coal of Bullmire creek should be an incentive for search for the Hazard bed on this fork, and especially as thick coal is reported on the Quicksand side of the divide.

PUNCHEON CAMP CREEK.

ELEVATION OF MOUTH, 900.

By Milburn Conley's house at the mouth of the creek, on the left, he has opened the following:

Fire Clay Coal.

Coal stain.		
Shale	11"	
Coal.		
Shale and flint fire clay	6"	Elevation 935.
Coal	8"	

On the left fork of this creek, a mile up from the river, are a number of openings into the No. 3 bed, some of which were not visited, as they were reported to be

about like those that were seen, all of which gave thin coal. The bed rises up-stream nearly as the Left Fork valley does. The two bed-sections given below are (1) from Green Howard's pit on the right, ½ mile up Left Fork and (2) from a 6-yard entry on the right, ¼ mile up Jake Fork, which is on the left a mile up Left Fork:

(1)			(2)		
S. S.	10 ft.		Shale	5 ft.	
Coal	12"		Coal	11"	
Shale	12"	Elevation 950.	Shale	7"	Elevation 980.
Coal	18"		Coal	18"	

On the left of Left Fork, 1½ miles up it, an opening by the road shows the parting 2½ feet thick, and the coal somewhat less than in the preceding.

No openings appear to have been made on Right Fork.

Opposite the mouth of Puncheon Camp creek the Arnett heirs have a 3-yard entry into what is probably the Haddix bed. Its bed section here is:

Shale	24"	
Coal	6"	
Clay	8"	
Coal	12"	
Shale	3"	Elevation 990.
Coal	25"	

On the left of the river, ⅛ mile above Puncheon Camp creek, cannel coal was found in an old prospect hole at elevation 1,155, evidently very thin. This is probably the Flag coal. About 50 feet higher are sandstone cliffs.

BULLMIRE CREEK.

ELEVATION OF MOUTH, 915.

A mile up the creek and ¼ mile up the Right fork, an usually well made 15-yard entry on Bird Howard's land gives what at first sight is a most excellent showing of the Hazard bed, but closer examination is somewhat disappointing, the bed-section giving:

Hazard Coal.

Shale	10 ft.	
Coal	18″	
Shale	6″	
Coal	2″	
Shale	1″	
Coal	1″	
Shale	1″	Elevation 1020.
Coal	11″	
Shale	1″	
Coal	32″	
Black slate	1″	

The lower seams are largely splint coal, which looks fine in the stock pits as one passes, but the shale partings in sampling were found to adhere, more or less, to the adjacent coal; the splint is dull in appearance, and coal marketed will probably prove very high in ash. The impression acquired is that the increased thickness over surrounding openings is gained largely at the expense of quality.

Excepting incomplete openings in the close vicinity no others are known on this stream.

On the left of the river, ½ mile above Bullmire creek, A. J. Brown has a 10-yard entry at elevation 1,020, into a bed which is probably the Haddix coal. It is of about the same thickness and quality as the coal next described, a small hill only intervening between the two openings.

SALT LICK CREEK.

ELEVATION OF MOUTH, 925.

On the left of a left branch, ¼ mile up Salt Lick, Joseph Allen has a 4-yard entry with the following bed-section:

Haddix Coal.

S. S.	10 ft.	
Shale	5 ft.	
Soft coal	11″	
Cannel coal	7″	Elevation 1030.
Splint coal	10″	

The splint and cannel coal are mined in one block the change from one to the other being gradual and al-

most imperceptible. The cannel looks good and the splint is an exceptionally fine bright rich coal, with lamination hardly visible.

On the left, 5 miles up the main (right) head of the creek, in front of Ellett Stowe's house, are two entries under massive sandstone, the bed-section being:

S. S.	10 ft.	
Cannel slate	7″	
Splinty coal	34″	Elevation 1100.

An inseparable half inch of bone coal 29 inches from the bottom detracts little from the value of the whole seam, which is very bright and good, much like the splint of the Allen opening, next preceding, and is probably the same bed, though in going up the creek the strata seemed to rise too fast to make it possible.

LONG CREEK.

ELEVATION OF MOUTH, 945.

The only coal seen on this creek is on the right, 3 miles up at elevation 1,085, 20 feet above the creek. But 2 feet thick with 4 feet of shale and then soft sandstone, it lies probably between Mr. Stowe's coal and the fire-clay coal.

The creek is peculiar in having no branches of consequence up to its forks, 3¼ miles from its mouth.

BUCK CREEK.

ELEVATION OF MOUTH, 955.

While working on this creek the barometer changed considerably and the heights of coal openings given are unreliable. It is believed, however, that no material error is involved.

RIGHT FORK OF BUCK CREEK.

A half-mile up the fork, on the left, ⅛ mile up a left branch by Proctor Wireman's house, he has a 4-yard entry into a 30″ coal-bed having 10 feet of sandstone roof. Apparently there is no parting. The bottom 7 inches, being in water, was not seen. The bed is 130 feet above the fork at the house and its elevation about 1,120,

too high for the Haddix coal (as appeared to be the case in going up to it), but it is probably of the Hazard bed—the sandstone roof rather indicative of the Flag bed.

A mile up the Right fork and 1/8 mile up a Right fork at J. M. Owens house, a bank on the right shows:

Coal stain	1 ft.	
Shale	5 ft.	
Coal stain	1½ ft.	Elevation 1055.
Coal	1 ft.	

One of these coals has been dug from the stream 100 yards farther up, and on the right 100 yards still farther up the Hazard bed has been entered, but the entry is partly filled. The following remains visible:

S. S.	5 ft.	
Shale (with two small coals)	10 ft.	
Cannel slate	5″	Elevation 1085.
Coal	30 to 36″	

The coal is reported 3 feet thick (probably including the cannel slate). The coals in the shale bank below seem to be offshoots from the main bed, a separation but just beginning in the Bullmire opening, a mile northwest from this one.

LEFT FORK OF BUCK CREEK.

Three openings, as given below, have been made into one bed on this fork. The sandstone roof, as in the Procter Wireman entry on Right fork, places the bed as the Flag rather than the Hazard, but this involves such a dip from the river up Buck creek and down the Right fork from Owens' entry as seems somewhat improbable. The three openings are:

7/8 Miles Up Left Fork and 1/8 Mile Up a Left Branch.

Shaly S. S.	36″	
Splinty coal	22″	Elevation 1080.
Knife edge parting		(above stream 25)
Coal	4″	

Ellett Wireman's on Right, 1 Mile Up.

S. S.	5 ft.	
Coal	19″	Elevation 1085.
Shale and coal	4″	(above stream 110.)
Coal	4″	

Irwin Bailey's (on left, 2 miles up.)

S. S.	10 ft.	
Coal	23″	Elevation 1055.
Knife edge parting.		(above stream 20.)
Coal	7″	

WHITLEY CREEK.

ELEVATION OF MOUTH, 970.

Three exposures of one bed on this creek give a down stream dip of 40 to 50 feet per mile, which would bring it about to the level of the Haddix coal, and one of the adjacent small seams it probably represents. The exposures are:

Smith Whittaker's on Left, 1 Mile Up.

Shaly S. S.	5 ft.	
Shale	1 ft.	
Coal	26″	Elevation 1065.
Shale	6″	(above creek 20.)
Coal	2″	
(Probably coal below.)		

On Left, 1¾ Miles Up.

S. S.	10 ft.	
Coal	12″	
Shale	1″	Elevation 1090.
Coal	15″	(above creek 10.)
Shale and coal	4″	
Fire clay.		

At Creek, 1⅞ Miles Up.

Coal	14″	
Shale	1″	Elevation 1110.
Coal	3″	
Shale	2″	
Coal	10″	

TRACE FORK.

ELEVATION OF MOUTH, 975.

Sam Wireman's house and store are ¾ mile up this fork: A mile up a right branch and ⅛ mile up a hollow on the right the following section of the Hazard coal shows in and over his entry, now hardly accessible:

Shale ..	20 ft.	
Shaly S. S.	10 ft.	
Shale and black slate	5 ft.	
Shale ..	2 ft.	
Coal ..	12″	
Shale ..	36″	Elevation 1120.
Coal ..	44″	

The upper 6 inches of this coal is a good soft block, the remainder a particularly rich-looking block and splint.

RIGHT FORK OF TRACE FORK.

TWO MILES UP: ELEVATION OF MOUTH, 1,025.

Three entries on this fork show the Hazard coal somewhat reduced from the preceding. They are as follows:

Adam Allen on Right, ¼ Mile Up, 30 Yard Entry.

Coal stain.		
Shale ..	5 ft.	
Coal ..	3 ft.	Elevation 1120.

D. E. Stacy on Left, ½ Mile Up, 6 Yard Entry.

Coal stain.		
Shale ..	15 ft.	
Coal ..	3″	
Clay ..	4″	Elevation 1190.
Coal ..	31″	

Stephen Wireman, ¾ Mile Up. ½ Mile Up Right Branch and ⅛ Mile Up Right Fork.

Shale ..	10 ft.	
Coal ..	9″	
Shale ..	5″	Elevation 1160.
Coal ..	33″	

A seam of carbonate iron ore shows in the point of the hill 30 feet under the Allen entry.

At a pit in the branch 60 yards above the Wireman entry the coal is almost four feet thick and the parting reduced to three inches.

LEFT FORK OF TRACE FORK.

2½ MILES UP: ELEVATION OF MOUTH, 1,035.

Bake Lick branch is on the left, ½ mile up this fork. On the right, ½ mile up the branch and 100 yards up the middle one of three inlets, a coal without a parting shows 29 inches thick under shale roof at elevation 1,105.

In the point of the hill on the right of the above Wiley Wireman has a pit sunk into the Hazard bed, at elevation 1,230, showing when visited 1 foot or more of splint or semi-cannel coal. The bed was reported 3½ feet thick, but whatever it may be there it would doubtless be more if down under proper cover. The bench here is very broad.

On the right, a mile up Left fork, the fire-clay, or the coal above it, gives, in a 2-yard entry of Wiley Wireman, 39 inches of coal with two thin partings included: Elevation 1,070, 15 feet above stream. The bed is reduced to 33 inches and one parting ⅛ mile farther up. The roof there is of sandstone.

Barb fork is on the left 1½ miles up the Left fork. From the stream, ½ mile up, coal has been taken, leaving a face of over 2 feet and no bottom reached. Its elevation, 1,160, leaves correlation too uncertain.

At. Cal. Hale's, 5½ miles up Trace, a pit in the point of the hill on the right, 140 feet above the creek, gives 28 inches of coal to a shale or clay bottom. This pit is also on a broad bench marking the coal of the Hazard bed; its elevation is 1,230. The 28 inches thickness of coal can only be regarded as a minimum: How much may have weathered away from the top or be underneath should be determined by drifting.

JOHN HOWARD BRANCH.

ELEVATION OF MOUTH, 985.

William Conley, 1/4 mile up, has an 8-yard entry on the left of and 1/4 mile up a right branch, on the first broad bench of the hill. Its bed-section is:

Hazard Coal.

Shale	10 ft.	
Coal	30″	Elevation 1090.

The lower part of this coal is hard and splinty. Possibly more coal lies below, as at the next following Hazard opening.

The fire-clay coal soon rises above drainage on John Howard branch. Two of its associate seams are probably represented by thin coals in the branch and ten feet above it, two miles from the river on the Road fork: Their elevations are 1,050 and 1,060.

A half mile above John Howard branch, A. Wireman's coal, taken from the river bed level, is probably of the fire-clay coal. It was not in condition for measurement when visited, but its thickness is estimated at 2½ feet.

In the point of the hill on the right of the river a mile above John Howard branch, James Neeley has entries, 120 feet above the river, one of which gives the following:

Hazard Coal, 10-yard Entry.

Shale	8 ft.	
Shelly coal	7″	
Clay	2″	
Coal	39″	Elevation 1105.
Shale	4″	
Coal	6″	

At the mouth of the entry the partings are but half as thick and the top coal two inches thicker than at the face as given.

The first foot of coal above the lower parting is very hard. The whole bed would have been better developed away from the point of the hill. The bench here is very broad.

MOLLY BRANCH.

ELEVATION OF MOUTH, 995.

Mrs. Howard, one mile up, has four exposures of the Hazard coal, 1/4 mile up the left branch, just below her house:

No. 1 (on Left.)

S. S.	10 ft.	
Coal	6 "	
Shale	2 to 3 "	
Coal	6 "	Elevation 1125.
Shale	½"	
Coal	28 "	

No. 2, 50 Yards Below No. 3.

Massive S. S.	20 ft.	
Coal	15"	
Shale	1"	Elevation 1125.
Coal	32"	

No. 3 (on Right.)

Thin bedded S. S.	20 ft.	
Coal	49"	Elevation 1120.

No. 4, on Right Branch and 150 Yards Above No. 3.

Shale	5 ft.	
Coal	6"	
Shale	3"	
Coal	15"	
Clay	1"	Elevation 1120.
Coal	26"	
Covered	10 ft.	
Coal	3"	

In No. 3 the upper 3 inches of the 28-inch seam is shelly, the 4 inches under that and 2 inches in the middle of the 16-inch seam higher up have a decidedly bony look, but, tried in a fire the ash, though evidently in large proportion, went completely to powder, while bone coal is regarded as such as retains its original form.

These four contiguous exposures illustrate markedly not only a locally conspicuous roll and changes of bed-section, but, chiefly important, the change in character of roof which, farther up the river, usually consists of a thick bed of shale containing a rider of coal.

Here the massive sandstone over No. 2 forms an unusually deep rockhouse, proving the strength and uniformity of the rock. At No. 3 the roof is in thin-bedded layers of sandstone wholly different from the preceding, while at No. 4 a complete change to shale is affected. This indicates a change in rock-making material rather than the decrease or increase of thickness of strata.

Mrs. Howard has another opening, just started, on the left, 1½ miles up Molly Branch, 15 feet above it, where the following section is uncovered:

Hazard Coal.

Coal stain	4″	
Shale	18″	Elevation 1140.
Coal	59″	

At river level on the left of it and on the right of the road, just below the mouth of Big Branch, coal for local use is taken and this section was obtained:

S. S.	15 ft.	
Shale	3 to 6 ft.	
Coal	6 to 8″	
Shale	1½ to 4½ ft.	Elevation 1005.
Coal with two thin partings	30″	
S. S. at river bed.		

This is probably of the fire-clay coal without its characteristic parting, the elevation being too low for the Haddix coal.

The change in thickness of shales here is gradual and not due to replacement as on Molly Branch.

BIG BRANCH.

ELEVATION OF MOUTH, 1,005.

Three openings on this branch give the Hazard bed and covering as shown below:

Widow Sheppard on Right, 3 Miles Up.

S. S.	5 ft.	
Shale	4 ft.	
Coal	1 ft.	
Shale	8 ft.	Elevation 1125.
Coal	1½ ft.	
Shale	8 ft.	
Coal	4½ ft.	

Hiram Johnson on Right, ⅞ Miles Up.

Shale	6 ft.	
Coal	6"	
Shale	4 ft.	Elevation 1135.
Visible coal	36"	

On Left, 1 Mile Up.

Shale	5 ft.	
Coal	23"	
Clay	1"	Elevation 1140.
Coal	33"	

None of this coal was found shelly, bony or otherwise impaired. That of the middle opening was hardly accessible and partly covered by fallen earth. The coal is probably about as thick as at the other openings.

BULL CREEK.

ELEVATION OF MOUTH, 1,015.

LICK FORK.—On the right, ¾ mile up.

A half mile up this stream and ¼ mile up a right branch Mr. Bradley has a 10-yard entry giving:

Shale	10 ft.
Hazard coal	69"+

The bottom 6 inches being in water was not seen.

At the mouth of this branch, 100 feet below the coal, is an impure limestone, nearly a foot thick, which has a tendency to weather into blocks about a foot square. If this is continuous it may serve as an aid elsewhere in finding the Haddix and Hazard coals above it or the fire-clay coal about 20 feet beneath it. A similar stone was found on Whiteley and other streams near by, but that deposit is below the fire-clay coal.

In the point of the hill on the right at the forks of Lick Fork, a mile from its mouth, carbonate iron ore is exposed twenty feet below the stain of the Hazard coal and perhaps 40 feet below the actual level of the bed. An abandoned entry into the coal shows on the hillside across the creek.

On the left, a mile up Bull creek, 100 feet above it, Dan Wireman has a 60-yard entry from which the following section was taken:

Hazard Coal.

S. S.	10 ft.	
Coal	12"	
Shale	5 ft.	
Coal	43"	
Shale	1"	Elevation 1130.
Coal	16"	
Fire clay	3"	
Coal	12"	

The bottom seam, not seen by the writer, is as reported by Mr. Crider of the State Geological Survey.

The upper 8 inches of the bed is shelly and would count for little in mining, more than its giving good head room. A "draw slate" 8 inches thick lies on the coal, above which is a moderately good holding shale, although it has fallen in several places in the length of the entry.

On the left, 1¼ miles up Bull creek 5 feet above the creek is 27 inches of coal between sanstones (one foot shale roof) at elevation 1,050, probably above the fire-clay coal.

Dan Wireman has an unfinished opening into the Hazard bed, 1½ miles up the creek, on the left, ⅛ mile up a right branch, which appeared to have slightly under 5 feet of coal—entirely covered on a second visit.

BRUSHY CREEK.

ELEVATION OF MOUTH, 1,020.

MUDDY BRANCH.—On the left, ⅜ mile up Pine branch; on the left, ½ mile up.

On the right, ¼ mile up each of these branches, William Shepard has openings as follows in the Hazard coal:

Muddy Branch, 7-Yard Entry.

S. S.	3 ft.	
Shale	1 ft.	
Coal	3"	Elevation 1120.
Knife edge parting.		
Coal	48"	

Pine Branch.

Earth.		
Coal	59" or more.	Elevation 1105.

In the entry the top 3 inches of coal is shelly, and 2 inches of block coal under the parting is poor.

ROAD FORK.—On the left, 1 mile up.

A half mile up this fork, on the right, ¼ mile up a left branch, Win Shepard has another opening, in which the bed is badly split up, as shown below:

Hazard Coal.

Shale	10 ft.	
Coal	23″	
Shale	12″	
Coal	12″	Elevation 1080.
Covered	36″	
Shale	5 ft.	
Coal	12″	

It is to be noted that, as obtained by barometer, this opening is 25 or 30 feet lower than those on either side of it. Also this opening is at the bottom of the broad bench, whereas the next following is 15 to 20 feet up on it. This leads to a possibility that this opening is below the main seam of the Hazard bed.

A fourth opening of Mr. Shepard's, an 8-yard entry on the right of road, ¾ mile up Road fork, gives the following:

Hazard Coal.

Earth.		
Coal	12″	
Shale	5 ft.	
Coal	21″	Elevation 1110.
Shale	1″	
Coal	28″	

This opening is but 75 feet below the low gap to Middle creek.

At (or near) R. B. Hale's, a mile above Brushy creek, Mr. Crider found the fire-clay coal 12 feet above the river; elevation, 1,040.

Back of and below Mr. Hale's house, on the left of the river, the Hazard coal is opened in a 3-yard entry, where the following section was obtained:

Shale ..	5 ft.
Coal ..	12″
Shale ..	9 ft.
Coal ..	59″

Elevation, 1160.

The coal is largely splint and makes an excellent showing burned in a grate.

T. B. Whittaker has a 6-yard entry at the head of a drain on the right, 1¾ miles above Brushy creek, showing nearly the same thickness as Mr. Hale's, but with 10 inches of shelly coal at the top. Possibly Mr. Hale's has this also, but water in the entry prevented access to the face. The covering differs, as shown in the following section:

Hazard Coal.

S. S.	10 ft.	
Coal ..	12″	
Shale ..	5 ft.	Elevation 1215.
Coal ..	58″	

WILL BRANCH.

ELEVATION OF MOUTH, 1,035.

Coal 16 inches thick has been taken from this branch, ¼ mile up it, which is probably underneath the fireclay coal. The strata rise nearly as the valley does.

On the right, ⅜ mile up, John Shepard has an 8-yard entry, the face now inaccessible, but measured at the mouth gave:

Hazard Coal.

Shale ..	6 ft.	
Coal ..	24″	
Mother coal	1″	Elevation 1215.
Coal ..	41″+	

At the face there appeared to be another one inch parting about 2 feet from the bottom. This appears to be the same opening visited by Prof. Crandall, as reported by him in Bulletin No. 10, although the covering differs considerably. His section and the analysis of his sample as given in that bulletin are repeated here:

Hazard Coal.

S. S.	
Shale	24"
Coal	21"
Bit. slate	1"
Coal	25"
Bit. slate	1"
Coal	11"
Bit. slate	1"
Coal	8"

Analysis.

Moisture	3.40
Volatile matter	32.80
Fixed carbon	56.30
Ash	7.50
	100.00
Sulphur	0.826

Mr. Crider gives the following bed-section found on J. B. Shepard's land on the right of Will's branch:

Hazard Coal.

Slate.		
Coal	6"	
Clay	4"	
Coal	18"	Elevation 1350.
Shale	14"	
Coal	18"	

GRASSY CREEK.

ELEVATION OF MOUTH, 1,040.

Mr. Crider also found on the river "by the road just below the mouth of Grassy creek:"

Fire Clay Coal.

Shale	20 ft.	
Coal	30"	
Fire-clay and shale	5 ft.	
Coal	12"	
Flint fire clay	3"	
Coal	12"	Elevation 1040.
Fire-clay	18"	
S. S.	24"	

At T. B. Whittaker's, ¼ mile up the creek, in it and in the road a 4-foot bed of coal was reported to the writer, but the pit was filled with wash and no sign of coal remained. Mr. Crider reports the following section for this bed (its elevation reduced to the present basis), below the mouth of Grassy creek:"

Top of hill—Elevation 1520.
Heavy S. S., forming cliffs.

Flag Coal.

Slate.		
Coal	6"	
Clay	4"	
Coal	18"	Elevation 1350.
Carb. shale	14"	
Coal	18"	
Interval	120 ft.	

Hazard Coal.

Shale	7 ft.	
Coal	26"	
Shale	5"	
Coal	4"	
Shale	1"	
Coal	3"	
Shale	1"	
Bl. slate	1"	Elevation 1230.
Coal	24"	
Shale	2"	
Bl. slate	1"	
Coal	16"	
Clay	1 to 2"	
Coal	30"+	
Interval	130 ft.	
Slate	4½ ft.	
Coal	3"	
Gray shale	24"	
Coal	8"	Elevation 1100.
Clay	4"	
Coal	10"	
Slate	2½"	
Coal	9"	
Interval	50 ft.	
S. S.		
Shale	24"	
Coal	3"	
Slate	4½"	Elevation 1050.
Coal	42"	

The second bed is probably a part of the fire-clay seam, the lower bed may possibly be the No. 3, but it seems too close to the fire-clay coal for that bed. The highest bed is given as the Flag, but the interval seems too great and it may be a higher coal. The rapid rise of strata up the creek makes it probable that the No. 3 bed may be opened above drainage there. If of the No. 3 bed a large area about the head of the river may be reasonably expected workable, readily accessible by shafts or slopes, if not in outcrop, and practically undiminished in area by erosion, the possibility urgently invites full investigation.

On the left, 1/4 mile up Grassy creek, in the drain behind Mr. Whittaker's house, several small seams of coal appear, which, at elevation 1,080 to 1,100, must be in the close vicinity of the fire-clay coal. Some of this group also appear on the river above Grassy creek near its mouth.

At the head of the right fork of this drain an unfinished opening at the bottom of a broad bench gives the following:

Hazard Coal.

Shale	7 ft.	
Coal	26"	
Shale	5"	
Coal	4"	
Shale	1"	
Coal	3"	
Shale	1"	
Black slate	1"	
Coal	24"	Elevation 1230.
Shale	2"	
Black slate	1"	
Coal	16"	
Clay	1 to 2"	
Coal	30"+	

Half of the bottom seam was in water, and the measurement therefore inexact, but there is no doubt of its being all coal.

At Albert Shepard's, 3/4 mile up Grassy, at the head of a small drain on the left, also at the bottom of a broad bench and 205 feet above the creek, the same bed is found

in an incomplete opening still more injured by partings and with the coal much reduced. Its bed-section follows:

Hazard Coal.

Rock and clay	5 ft.	
Coal	16″	
Shale	16″	
Coal	8″	
Covered	30″	
Shale	16″	Elevation 1280.
Coal	11″	
Black slate	2″	
Coal	12″	

The height of this bed above the creek gives ample room for the appearance of the No. 3 bed above drainage, if its interval below the Hazard is no greater than was found down the river.

At Elkanah Gearhart's, a mile above Grassy creek and 190 feet above it, an unfinished opening gave to Mr. Crider the following section:

Hazard Coal.

Slate	10 ft.	
Coal	15″	
Slate	3½ ft.	Elevation 1240.
Coal	48″	

Full development may give thicker coal. This was in process on the writer's visit, but at that time a fall of earth had nearly hidden the whole.

QUICKSAND FORK.

Sam Bailey has an opening on the point of a hill on the right, ½ mile up the fork, in which the following bed-section shows. With scant covering the coal has doubtless weathered away considerably and the parting, perhaps, crept in:

Hazard Coal.

Shale	2 ft.
Coal	12″
Clay shale	7 to 12″
Coal	34″

This and the next preceding opening are on the first broad bench above the river.

At Gardner Bailey's, 2½ miles above Grassy creek, in the point of a hill, ¼ mile up a right branch, on a good bench, but with another equally good 80 to 90 feet lower, an abandoned entry shows 2½ to 3 feet of coal under 10 feet of shale. This is of the Flag bed, its elevation 1,370; the river about 1,090.

At the mouth of the branch, or, at Mr. Bailey's house, the Flag bed is probably about 300 feet above the river, the fire-clay coal 100 feet above, and the No. 3 should be found within 40 feet of the river, probably above water level but possibly below. Both give justification for search, the fire-clay coal, across the divide to the south, in an opening on the head of Salt Lick creek, having 40 inches of coal and but 4 inches of parting.

THE ELKHORN COAL.

The Elkhorn seam is found of good thickness across the divide on Big Sandy waters, but is everywhere beneath drainage in this section. Its place would be probably 250′ below the surface at the mouth of Grassy and less than that with the rising dip down the river. The well known character of this coal would seem to justify some drilling with a core drill to test its presence and thickness here.

COALS ON THE NORTH SIDE OF THE NORTH FORK OF KENTUCKY RIVER IN PERRY AND KNOTT COUNTIES.

BY

JAMES M. HODGE.

This report follows a recent examination of all developments which were available in the region it covers, viz: The Lost creek watershed above Cockerel Fork in Breathitt County, and the drainage area of the North Fork of Kentucky River on the north side of the river from Lot's Creek to Carr Fork, inclusive, with the exception of that part of Carr Fork above Irishman Creek. The report is made along the lines adopted in Bulletin No. 11 of the Kentucky Geological Survey, to which reference is frequently made, and amplifies and corrects that report to the extent of the territory covered.

New topographical maps, on a large scale, of most of this field issued jointly by the Kentucky Geological Survey and the U. S. Geological Survey, admit of location of openings with a great degree of accuracy, and altitudes marked frequently along streams, roads and hilltops, as well as on the maps, have aided very much in using the barometer for getting heights of openings and determining correlations and inclinations of strata. It should be noted, however, that barometric readings can never be relied upon implicitly, but are often in error and always subject to correction.

There are numerous altitudes given in this report, and they are expected to replace those given in the earlier report.

Beyond mentioning the fact of a general northwest dip throughout this restricted field, it is necessary to say little more here in regard to structure. The closer work done has revealed numerous minor cross dips and reverse dips, some of which are pointed out when treating of the localities where they occur, while others are too ob-

vious to need mention. Outcrop surveys are needed for final determination of local dips before mining operation are begun. This is work for property owners and is now well under way.

With such knowledge of them as is already acquired, the outcrops of two of the beds at least, the fire-clay and the Flag coals, can be drawn on the map, their areas calculated and from their known thickness, the available coal be determined with sufficient accuracy for general purposes. The principle beds above drainage in this region and approximate intervals between them, with the notation locally used to describe them added, are as follows:

Hindman Coal.
Interval 100 feet.
Flag Coal (No. 7).
Interval 40 to 80 feet or more.
Hazard Coal (No. 6).
Interval 100 feet.
Haddix Coal (No. 5).
Interval 200 to 235 feet.
Fire-clay Coal (No. 4).

Three other coals, one a rider to the fire-clay coal, one midway between the Haddix and Hazard coals, and the third between the Flag and Hindman coals, sometimes assume a workable thickness, but it is very doubtful if they do so over much area. These intervals are variable without apparent regularity, though there seems to be an approach to a uniform increase of interval between the Hazard and Flag coals from 40 feet on Lost creek to 80 feet on Lot's creek and possibly to 100 feet on Irishman creek. The lowest strata exposed are at the mouth of Irishman creek, 160 feet below the fire-clay coal, and the highest are at the head of Trace Fork of Irishman, probably 300 feet above the Hindman coal—in all about 1,000 feet of measures. The lowest 100 feet of this carries no coal of value nor any conspicuous rock. At the top of this 100 feet is a thin coal, apparently constant, and underlying a sandstone which forms the lower cliffs at the river above Hazard and carrying the Whitesburg coal, with more or less shale accompanying it, at varying distances from the fire-clay coal above it, but

normally about 30 feet. The Whitesburg coal, above drainage in this field only at and above Hazard, is in places wholly cut out by this sandstone, but while often carrying enough coal for working is so cut up by partings as to ruin it. Only at one place, on Irishman creek, does it show three feet of clean coal. The fire-clay coal is below drainage on the upper half of Lost creek, its bed-section before going under the creek showing partings which give to its three feet and over of coal an unattractive appearance. On Lot's creek the upper part of this bed is clean, varying in thickness from workable to non-workable under present conditions. At its thickest it appears in large part as cannel coal. From the mouth of Lot's creek up the river to Carr Fork and thence to Irishman creek there is a gradual increase in thickness of the fire-clay coal, but with a number of fluctuations: the upper bench of coal is remarkably constant at 3 to 3½ feet over a large area, while the lower bench adds an increasing amount of coal of doubtful value owing to the impurities in it. The quality of the upper bench is fine for domestic use and for steam, and its uniformity in appearance throughout its thickness is striking. On Carr Fork it is usually without regular cleavage. The peculiar parting in this bed is still more singular in a part of this field in that it consists of two distinct parts, the lower the usual brown (sometimes black) flint clay, the upper part a combined black slate and fire-clay, sometimes so largely bituminous as to make the closest examina necessary to determine it from splint coal before it is mined. But slowly affected by weather, it is conspicuous in the dumps from entries and often elsewhere below the bed and serves for identification when entries are closed. To it is applied here the name of "black jack." A peculiarity in the roof of this coal, seen in so many places as to lead to the impression that it is exceptional otherwise, is that where shale covers the bed on outcrop, on going a few yards underground the shale changes to sandstone; sometimes this flakes off near the mouth but does not farther in. This change occurs even when no sand whatever can be detected outside either by eye or with hammer. This necessitates doubt of any shale which has been exposed to weathering if it may not really be a weathered sandstone. The rider to the

fire-clay coal shows a fair thickness only on Lot's creek and at one locality there. The adjacent rocks vary from shales and thin sandstones away from the river to thick, massive sandstones in the vicinity of the river which apparently cut out this bed. From these shales or sandstones up to the Haddix coal there is generally an alternation of shales and thin bedded sandstones, the latter predominating and supplying most of the flagstones required for local use.

For a few miles on Lost creek the Haddix coal makes an excellent showing of from three to five feet, but before going below drainage it becomes thin, to reappear on Trace Fork of Lot's creek with over four feet of coal. On the main creek and upper branches, however, along the river and on Carr Fork, it appears to be lost, no openings in it being known except at the head of Kelly Fork of Lot's creek, where a thick bed has been found which is presumably the Haddix. From the Haddix coal to the Hazard coal is largely massive sandstone, the twenty feet of sandstone close under the Hazard being particularly durable, presenting cliffs of that thickness at frequent intervals. Half way between the Haddix and Hazard beds is a coal, apparently constant, with over three feet of coal on the upper forks of Lot's creek. To this bed is given the name of "Young" coal. The Hazard bed, with five and seven feet of coal on Lost creek, is found workable in a few places elsewhere in this field; it seems to be particularly uncertain as to partings, and much more development is needed to give it the assured value which is indicated by its thick coal. Shales of considerable thickness usually overlie the Hazard coal; above these is a cliff making sandstone up to the Flag coal. Throughout the field this Flag coal is the most reliable in thickness, ranging from 87 inches of clean coal on Lost creek to over three feet as a minimum, and probably averaging four to five feet. Openings, however, are not so numerous anywhere in the field as to warrant mining without closer investigation in each particular locality where such work may be proposed. Over the Flag coal is a hard, massive sandstone, frequently the roof of the bed, which probably extends to the next coal, about 50 feet higher. Little is known of this higher coal, as it lies too near the tops of the hills to carry much area. It

is three to four feet thick on Gregory branch, and less than three feet, including a parting, on Yellow creek at the only opening found in condition to measure. In this report this will be called the "Francis" coal. Next above the Francis coal is a hard, thick sandstone which caps the ridges over a large part of the field. The Hindman coal, because of its great thickness, nearly ten feet at the head of Irishman creek, has more local reputation than development, being assumed to maintain that thickness, whereas at the head of Lost creek it appears to be but four feet thick. Between Irishman and the head of Lot's creek is the only hill high enough to give a workable area, a large one being needed for a coal so difficult of access as this. The sandstone directly over this coal is extremely friable and makes a bad roof. It is probably 70 feet thick, with a hard cap, which gives rise to many of the peaks in the field. Strata above this are to be found probably only between Irishman and Lot's creeks and have not been investigated.

Following is a description in detail of coal openings and natural exposures in this region visited this year, together with references to former information published. It includes all openings in the field which were in condition for examination at the time so far as they could be determined, many of them being partly closed. The general use of coal by residents instead of wood as in earlier years, has resulted in such development of the coal beds as to render their correlation far more reliable than under former conditions. The description is arranged in geographical order, beginning at the mouths of the streams and following each one in succession, with its tributaries, to its head. The terms left and right are used invariably as when looking up stream. Surface distances, given in miles, are fairly accurate having been measured generally on the new maps whenever they were available. Underground distances, given in yards, are all by estimation. Thickness of strata, given in feet, are approximate only; given in inches are exact. Altitudes of openings determined by barometer are still subject to correction, usually but slightly so. When disagreeing with those given in Bulletin No. 11 of the Geological Survey, figures given here take precedence. Entries are often partially closed at the mouth by fallen earth, so that

six inches to a foot of water stands in them; such are designated here as "wet" entries. Names of owners or former owners of lands are given preference to names of companies owning coal, as openings can be more definitely located in that way.

LOST CREEK.

On the left of Lost creek, one-eighth mile below Cockerel Fork, and again one-quarter mile above Cockerel, on the left of a small drain, the fire-clay coal is opened with the following sections:

Below Cockerel.

Sandstone	3 ft.
Shale	5 ft.
Coal	25″
Parting	3″
Coal	13″
Altitude, 835.	

Above Cockerel.

Shale and shaly sandstone	10 ft.
Coal	5″
Shale	1″
Coal	18″
Shale	3″
Coal	16″
Parting	4″
Coal	10″
Black slate.	
Altitude, 840.	

Elevation of Cockerel Fork 805

The first was measured at the mouth of a long entry, the second at the face one yard in. The partings consist of an indeterminate rock apparently between a common shale and the characteristic flint fire-clay.

Up Cockerel Fork the coal goes under drainage, but up Lost creek it rises with the stream, being 25 feet above at the mouth of Ten Mile creek and 33 inches thick there without parting. The rider has 26 inches of coal there. The Haddix coal, as found directly opposite and 200 feet higher than the mouth of Ten Mile, has the following section:

Haddix Coal.

Coal	23″
Shale	4″
Coal	4″
Shale	1″
Coal	2″
Altitude, 1015.	

TEN MILE CREEK.

On the right and 1¼ miles above Cockerel Fork. Altitude at mouth, 815.

No satisfactory coal appears to have been found on this creek, those openings made having all fallen in. On the left and over the Left Fork divide, however, is an opening on Low Gap branch which encourages the hope that the bed has been overlooked here.

LOW GAP BRANCH.

On the right, 3½ miles above Ten Mile creek. Altitude at mouth, 860.

On the right drain of the right fork of this branch, ¾ mile from Lost creek, Green Noble has an opening in the Hazard bed giving the following section:

Hazard Coal.

Sandstone	10 ft.
Block coal	13″
Shale	3″
Block coal	1″
Shale	7″
Block coal	31″
Clay	1″
Block coal	20″
Black slate.	
Altitude, 1130.	

But a few inches of the bottom coal was seen, and its 20 inches may include a parting, there being 18 inches of water in the entry.

COLLINS BRANCH.

On the left, 2½ miles above Ten Mile creek.

The section of the Collingsworth opening on the Flag coal is taken from Bulletin No. 11, but with corrected elevation.

Flag Coal.

Clay.	
Coal	15"
Cannel and Splint coal	18"
Clay	1"
Coal	16"
Clay	1"
Coal	8"
Altitude, 1195.	

FIFTEEN MILE CREEK.

Altitude of mouth, 910.

Opposite the mouth of this creek and ten feet above it is eigtheen inches of coal under ten feet of shale and upon five feet of sandstone. This is probably the fire-clay coal rider, the main bed having gone below the creek about a mile farther down stream. A quarter of a mile up Fifteen Mile, on the left and a quarter of a mile up a left branch, the Hazard coal gives in a partly closed, wet entry, under fifteen feet of shale, six and a half feet of coal, including thin partings near the top. Its altitude is 1,165. On the Combs and Horton tract, one mile up Fifteen Mile, three coals are shown as follows. Opening on left by the road and one-quarter of a mile up right branch:

Flag Coal.

Shale	5 ft.
Coal	1"
Shale	2"
Coal	61"
Altitude, 1180.	

Ten yard entry on left of same branch and near its mouth:

Hazard Coal.

Shale	10 ft.
Coal	6"
Shale	1"
Coal	5"
Shale	1"
Coal	69"
Altitude, 1140.	

The lower thirty inches is block coal with plates of splint. That these two similar sections are on separate beds is evident in the passage from one opening to the other. In addition to the shale roof, there is a bed of sandstone between them. The analysis of the Flag coal, taken from Bulletin No. 11, is:

Analysis.

Moisture	2.48
Volatile matter	35.51
Fixed carbon	52.43
Ash	9.58
Sulphur	1.05
Phosphorus	0.033
Specific gravity	1.337
Coke	62.01
Total carbon	70.95
B. T. U.	12,958

At the mouth of the same branch the Haddix coal, or a part of it, 14 inches thick, lies at an altitude of 1,060. From the head of this branch, across the divide, half a mile down Grapevine creek, on its right and below the trail is a ten-yard entry which from its altitude is presumed to be on the Hazard coal. Water in the entry prevented ascertaining the thickness better than is given here and may have concealed a parting at the bottom:

Hazard Coal.

Shale	7 ft.
Coal	1"
Shale	1"
Coal	5"
Shale	1"
Coal	6"
Shale	1"
Coal	60"

Altitude, 1135.

This opening augurs well for continuity in thickness in this direction.

SIXTEEN MILE CREEK.

Altitude of mouth, 925.

On the right, half a mile up, at water level (965) is exposed two feet of coal and shale at the base of a shale cliff about 65 feet high. Two limestone seams about six inches thick traverse this cliff at heights of 35 and 45 feet. On a left branch, 1¼ miles up, a two-yard entry, fallen in, still shows somewhat over 5 feet of coal under 18 inches of coal and partings and those under 10 feet of shale. Its exact altitude is 1,192 and is indicative of the Flag coal.

Strong branch, on the right, 1¼ miles up has exposed, at its mouth (altitude, 995), 30 feet of the shale in the high cliff lower down the creek. A mile up Strong branch, on the right, beside the trail to Grapevine creek, a 4-yard wet entry gives the following section:

Hazard Coal.

Sandstone	5 ft.
Shale	12 ft.
Coal	2″
Shale	1″
Coal	4″
Shale	3″
Coal	68″

Altitude, 1165.

The similarity in this vicinity of the Hazard and Flag coals, only 40 feet apart, makes correlation especially uncertain in isolated openings. Altitude here is the only guide and that appears to place this coal as of the Hazard bed.

Hiram branch is on the left, two miles up Sixteen Mile creek. Altitude of mouth, 1,060. On the right, at the mouth of Hiram branch a prospect on the Flag coal gives the following section:

Flag Coal.

Sandstone	24″
Shale	18″
Coal	1″
Shale	6″
Coal	2″
Shale	3″
Coal	52″

Altitude, 1220.

In this vicinity there is but little difference in the appearance of the Flag and Hazard coals, each being in the main block coal with more or less splint coal interleaved. In this Flag opening there appears to be a little more splint coal than the Hazard bed has shown. An opening on the Hazard bed at altitude 1,180, was so fallen in when visited that little coal could be seen, but a thick bed was evident. On the left, at the mouth of the branch, the Haddix coal appears to be cut out by sandstone which forms a 20-foot cliff from the branch. In a drain cutting into this sandstone, 1/8 mile up the branch, is three feet of alternating coal and sandstone and for the next 1/8 mile or more, up to the first left-hand branch and in the point of the hill beyond, the stain of the bed is conspicuous at this level. On the left, half a mile up, a prospect five feet above the branch, partly covered, shows some 3½ feet of coal bed with one thin parting visible. This, the Haddix coal, at altitude 1,090, goes below drainage, ¾ mile up the branch, having there a black slate floor. On the right, one mile up and 20 feet above the branch, the Hazard coal was opened and, partly covered, still shows the following section:

Hazard Coal.

Shale.	
Sandstone	2 ft.
Coal	25"
Shale	6"
Coal	48"+
Altitude, 1180.	

It is probable that the lower 48 inches or more is all coal, giving a bed of somewhat over 6 feet of coal with but 6 inches of parting. On the left, 1/8 mile above Hiram branch under 6 feet of shale (in contrast with the exposure along Hiram branch), the Haddix bed has been opened at altitude, 1,085. This opening, fallen in, still showed a bed over 5 feet thick, including a parting of 5 or 6 inches about 18 inches from the bottom. The floor is a black slate. This opening, as well as those on Hiram branch, are on Wilson Campbell's land. Coal of unknown thickness, reported taken from the creek, 2½ miles up, altitude 1,120, is probably of the Haddix bed.

LOW GAP BRANCH.

On the left of Lost creek, ½ mile above Sixteen Mile creek. Altitude of mouth, 945.

Shales are exposed on this branch almost completely up to the Haddix coal, which is opened in a right drain ¼ mile up and has about 33 inches of coal, without parting, lying under 25 feet of sandstone. Altitude, 1,035.

On the left of Lost creek, ¾ mile above Sixteen Mile creek, two short entries, the higher one 100 yards farther up stream than the lower one, gave the following sections:

Hazard Coal.

Sandstone	6 ft.
Shale	6 ft.
Coal	15"
Shale	1"
Coal	61"
Altitude, 1140.	

Haddix Coal.

Sandstone	7 ft.
Coal	39"
Knife edge parting.	
Coal	7"
Altitude, 1030.	

The sandstone over the Hazard bed is here extremely friable. These and the next preceding Low Gap branch opening, are on Mahlon Jones' land. On the right, one mile above Sixteen Mile, a prospect into the Hazard bed shows, under 5 feet of shale, about 6 feet total thickness, including 9 inches of shale one inch from the top. Altitude, 1,155.

WILL BRANCH.

On the left, 1¼ miles above Sixteen Mile creek.

A half mile up this branch, on the right fork and 15 feet above it, Mahlon Jones has a 10-yard entry into the Haddix bed showing 46 inches of coal under 10 feet of sandstone. Altitude, 1,075. This is a hard, bright, block coal containing a little splint.

CAMP BRANCH.

On the right, 1¾ miles above Sixteen Mile creek.

No coal in condition to measure was found on this branch, but the following section was obtained:

Cannel coal and black slate (thin)	1320
Flag coal (?) (prospect)	1210
Coal (reported about 18 inches)	1125
50-foot sandstone	1055
15-foot sandstone	1035

The sandstones are exposed in the bed of the branch from ¼ to ½ mile up it and the coals have been incompletely opened on the right ½ mile up. The place of the Haddix coal appears to be in the 5-foot interval between the two sandstones, giving about the usual interval to the Flag coal at 1,210. The 18-inch coal is then probably 30 to 40 feet below the Hazard bed. The cannel coal is in the place of the Hindman bed, as it has been developed farther east, but there have been no indications there of either cannel or slate. On the right of Lost creek, above Camp branch, the Haddix coal has been opened but has been entirely covered again. Apparently a thick coal was found. Its altitude is 1,050.

BOWMAN BRANCH.

On the left, 2 miles above Sixteen Mile vreek.

On the left, ¼ mile up this branch, N. Combs has a prospect into the Haddix bed, giving nearly or quite 60 inches of clean coal at altitude 1,070. Five feet of shale covers this coal with 15 feet of sandstone over that. At J. E. Campbell's, on the left, 2¼ miles above Sixteen Mile and ¼ mile below Rock Fork, an entry is driven into the Haddix coal at altitude 1,070, which gives at its mouth 64 inches of coal, but 10 yards in a roll has cut it down to 40 inches. The entry was then driven to the left alongside the roll for about 20 yards and continued in thick coal, 56 inches at the face. The parting seen on an earlier visit is not continuous. The coal is a fine, hard, bright block. Analysis (from Bulletin No. 11) is:

Haddix Coal.

Moisture	2.09
Volatile matter	38.61
Fixed carbon	54.21
Ash	5.09
Sulphur	0.83
Phosphorus	0.007
Coke	59.30
Specific gravity	1.297
Fixed carbon	74.24
B. T. U.	14,018

Attention is called here to the two openings on Tom's branch at Troubesome creek, only a half mile to the north and given in Bulletin No. 11, page 52, where the two coals shown as Flag and Hazard, should be Hazard and Haddix at altitudes 1,190 and 1,090 instead of as there given.

Rock Fork.

2½ miles above Sixteen Mile Creek.
Altitude of mouth, 1,040.

In the cliff on the left at the mouth of this fork and 30 feet above it, a thin coal was reported found which is evidently the Haddix, indicating that the roll found in the Campbell entry continues indefinitely up Lost creek. On the left, at the head of Rock Fork and ¾ mile up, a prospect on Dr. Jones' land gives:

Flag Coal.

Shale	5 ft.
Coal	8″
Shale	2″
Coal	71″

Altitude, 1240.

This is a block coal, the lower 30 inches hard.

Considerable prospecting appears to have been done above Rock Fork in search for the Hazard coal, under the supposition that it might rise with or faster than Lost creek, but without success. The coal is apparently completely cut out by sandstone a quarter of a mile above Rock Fork and is certainly under drainage at the mouth of Laurel Fork.

LAUREL FORK.

On the right, one mile above Rock Fork.
Altitude of mouth, 1,110.

Massive and thin-bedded sandstones are exposed along this branch with little break to the Hazard coal, but at the mouth of a branch 5/8 mile up the following intervenes:

Sandstone.	
Shale	5 ft.
Coal	3″
Fire-clay	2 ft.
Altitude, 1135.	

At the forks of the creek, a mile up, is 22 inches of coal under 8 feet of shale—the Hazard bed or part of it, at altitude 1,170. On the left, a quarter mile up the right fork and 10 feet above it, an incomplete prospect in a broken hillside gives the following in which the upper bench of coal is a squeezed, shapeless mass and the lower bench, partly covered may contain a parting:

Flag Coal.	
Massive sandstone	5 ft.
Coal	2½ ft.
Shale	9 ″
Coal	4 ft.
Altitude, 1220.	

By means of this opening combined with those on the Flag coal on Rock Fork and with the Mahlon Jones opening into the same bed, a northwest dip of about 50 feet per mile is found. If the dip were uniform the 22 inches of coal at altitude 1,170 must be at about 1,155 at the mouth of Laurel branch, giving strata practically level to the coal next mentioned up Lost creek, but with their depression here as usual along the main streams, there still remains a slight rise of strata up Lost creek which continues to its head. On the right, two miles above Rock Fork, at Robert Combs' (formerly Fish Napier's) on the right of the hollow, the stain of the Hazard bed shows, unfavorably, under five feet of shale at altitude 1,185 and a new 3-yard entry into the

Flag coal gives 48 inches of coal under 10 feet of sandstone. Altitude, 1,240.

On the left, 2½ miles above Rock Fork and by the road ascending the hill at the head of Lost creek, is an exposure which, combined with an opening beyond, below the road, gives the following:

Flag Coal.

Sandstone	8 ft.
Coal	34 "
Hard parting	¼"
Coal	19 "
Altitude, 1245.	
Interval (shaly S. S.)	
Sandstone	5 ft.
Shale	5 ft.
Coal	7"
Shale	3 ft.
Altitude, 1215.	

It appears that the Hazard bed is reduced on Laurel Fork to 22 inches and to 7 inches here, but it is not impossible that the seam splits and this thin seam represents only a part of the bed and that the main body of the coal is a few feet below.

A reported 48 inches of fine coal on the level of the gap to Lot's creek and 150 yards to the right of it, at altitude 1,405, is of the Hindman bed unless the anticline here is sharper than supposed and the next bed below is brought up to this level.

LOT'S CREEK.

The altitude of the mouth of this creek is about 820, the highway bridge there being 842. Heavy sandstone underlying the Fire-clay coal makes a rockhouse into which the highway goes just above the mouth of the creek, about 6 inches of coal at altitude 835 (probably an offshoot from the Whitesburg coal), showing at the base of the cliff. Farther up the creek the road rises to the top of that sandstone and the stain of the Fire-clay bed is visible in several places and the sandstone above it has become shaly giving place almost altogether to shale farther up the stream. An opening into this bed on the Helen

Combs branch, is taken from Bulletin No. 11 with corrected altitude—

Fire-clay Coal.

Sandstone	20 ft.
Shale or S. S.	18"
Coal	37"
Altitude, 890.	

TRACE FORK.

On the right, one mile up Lot's creek.

The Holliday entry on the fire-clay coal shows 41 inches of coal with one inch parting three inches from the top at altitude 890. The Fire-clay bed goes below drainage, ¼ mile above Jake Fork about where two inches of coal, a remnant possibly of its rider, shows on the right under 20 feet of sandstone and above 4 feet of shale.

LOST CREEK, ROAD FORK.

On the left of Trace Fork and one mile up it.

On the right, a mile up this fork, the Haddix coal is opened in a long rockhouse and also beside its eastern end. From these places the following measurements were obtained:

Under Cliff.

Coal	38"
Shale	30"
Coal	3"
Shale	3"
Coal	16"

10 Yards East.

Coal	34"
Shale	11"
Coal	19"
Altitude, 1160.	

The identity in thickness of the two coal seams of this eastern section with those of the Flag coal at the head of Lost creek, would ordinarily lead to their correlation, but there is no other reason for supposing such an extreme reversal through Lost mountain, of the gen-

eral dip as that would entail. Even assuming the opening to be of the Haddix bed (which is done with confidence) and the fire-clay coal to be 200 feet under it, a slight dip down stream and against the general dip is involved. Following the road up from this coal the bench of the Hazard coal is very evident at altitude 1,245 and 35 feet of sandstone above the Flag coal at altitude 1,300. Forty feet more of sandstone shows from 1,365 to the gap at 1,406 where the Hindman coal should be found: 30 feet above the gap some 40 to 50 feet of sandstone cliffs appear.

PIGEON ROOST ROAD FORK.

On the right of the Lost Creek Road Fork, 3/4 mile up from Trace Fork.

In the point of a hill where it is likely coal in a normal condition could not be found, a quarter mile up this fork, an old prospect and exposure under it gives—

Sandstone	2 ft.	
Coal	15″	
Shale	1″	
Coal	15″	—Haddix Coal.
Shale	10″	
Coal	24″	(possible)
Altitude, 1,115.		

Covered	40 ft.
Shale	30 ft.
Blac Slate	6″
Fire clay	18″
Altitude, 1,045.	

By the road, 3/4 mile up, a foot of coal and shale and a 10-foot sandstone cliff appears to represent at least a part of the Haddix bed at altitude 1,130. In a branch on the right, 7/8 mile up, thin bedded standstone occupies the apparent place of the Haddix bed at 1,125 to 1,130 and 35 feet of massive sandstone lies directly on that, but an error in heights is possible or the coal may have dipped below the sandstone. A quarter mile up and in the branch, coal reported 23 inches thick has been opened. Near by, on the head of Trace Fork, this coal lies 55 feet

above the Haddix bed. On the left of the road, a few yards up from the foot of the hill and one mile from the Lost creek road is—

Flag Coal.

Massive sandstone	5 ft.
Shale	10 ft.
Hard, block coal	46″

Altitude, 1,260.

To the excellent showing of coals on Pigeon Roost branch of Troublesome creek as given in Bulletin No. 11, page 56, can be added the William Brewer opening, on the right, at the head of Pigeon Roost branch,

Flag Coal.

Sandstone and shale	5 ft.
Shale	5 ft.
Coal	32″
Hard parting with coal	6 to 9″
Shale	6″
Coal	9″
Shale	7″
Coal	5″

Altitude, 1,270.

showing that full dependence on thick, clean coal is not justified in this as in other beds without thorough exploitation. At water level, ¾ mile up from the Lost creek road and two miles from Trace Fork the following section is exposed:

Sandstone	5 ft.
Shale	15 ft.
Black slate	6″
Coal	1″
Shale	1 ft.
Sandstone	2 ft.

Altitude, 1,030.

On the left at this point is a prospect into the Flag coal which is remarkably similar to the one given above on Pigeon Roost branch—

Flag Coal.

Sandstone	3 ft.
Coal	34″
Black slate	12″
Shale	5″
Coal	11″
Shale	2″
Coal	4″

Altitude, 1,310.

On the left, 1/8 mile farther up, is an opening now closed, into the Haddix bed at altitude 1,150. This was given in Bulletin No. 11 as "Hazard." The section is:

Haddix Coal.

Shale	5 ft.
Coal	11″
Shale	13″
Coal	38″

Altitude, 1,150.

Opposite this, on the right of Trace Fork, the Hazard coal is now open in a 20-yard entry as follows:

Hazard Coal.

Shaly sandstone	3 ft.
Shale	2 ft.
Coal	53″

Altitude, 1,250.

Between the Haddix and Hazard beds is here reported a coal 18 inches thick at altitude 1,205. These Trace Fork openings are on land of Charles Godsey.

JAKE FORK.

On the right, one mile up Trace Fork.
Altitude of mouth, 880.

The Fire-clay coal, lying nearly level, goes under this stream about 1/4 mile up it and beyond this the shales of the high cliff on Fifteen Mile creek of Lost creek are recognized, but with some variations. At water level, 3/4 mile up, is five feet or more of black slate, altitude 920, and 1 1/4 miles up the following section with base at the creek—

Sandstone	15 ft.
Shale	18"
Coal	6"
Fire clay	2½ ft.
Shale	5 ft.

Altitude, 940.

One-eighth mile farther up three thin coals appear in the 10 feet of shale under the sandstone.

SANG FORK.

On the left, 1½ miles up Jake Fork.

On right, ¾ mile up, a wet entry gives at its mouth 47 inches of coal under 5 feet of sandstone at altitude 1,220. The under surface of the sandstone undulates in slight curves, the top of the coal apparently conforming to this uneven surface. On the left of Jake Fork, a quarter of a mile above Sang Fork and the same distance due south of the preceding entry, the same bed at the same height, has 50 inches of coal, the lower 20 inches particularly bright, rich looking and hard. Thirty feet below both of these openings is a prominent bench, altitude 1,190, indicative of the Hazard coal and the coal at 1,220 the Flag, but if such were the case, the strata must rise at a rate of about 80 feet to the mile both westward and eastward, the Flag coal on main Trace Fork and Jake Fork, presently to be noted, requiring such rise; moreover these two latter openings are alike in section but differ materially from the two intermediate ones in line with them. A similar objection applies, though in less degree, to the assumption that the two openings at altitude 1,220 are of the Hazard bed and the broad bench 30 feet under the Hazard is out of place. As the Haddix bed, the objection as to dip applies, but in reverse direction, and the bench is still more out of place. The conclusion is then forced that this bed lies between the Haddix and Hazard, heretofore unknown as workable, and grown from the 18 and 23 inches on the Trace Fork on the west and the 3 inches of Laurel Fork of Lost creek. With this the case, the bench marks the close proximity of the Hazard bed and the fire-clay coal must lie for a mile down stream at or within a very few feet of the level of Jake Fork. Additional reason for this

correlation is found on Young Fork, this bed being given here the name of "Young" in consequence. If this deduction is true, there is a line of strike from the Trace Fork openings to near the head of Jake Fork almost at right angles to the normal strike of the North Fork field.

On the right of a right branch, 2½ miles up Jake Fork, Noah Smith has an abandoned entry in which 1½ feet of coal could be seen; the bed is probably 4 feet or more thick, under 5 feet of shale and shaly sandstone. It is the Haddix coal at altitude 1,160. On the same land, ⅛ mile farther up Jake Fork, a 7-yard entry gives the following:

Flag Coal

Sandstone	4 ft.
Coal	21″
Blackjack	3″
Shale	3″
Coal	13″

Altitude, 1,300.

On the point of the spur between these two Smith openings an uprooted tree has exposed an abundant stain of the Hazard bed at altitude 1,255. Going up the left fork from the Smith openings, strata are seen to rise with unusual rapidity, faster than the rise of the creek, and shales continue conspicuous. At 2⅞ miles up, on the right of the upper left fork, a covered prospect gives coal at altitude 1,145 with 5 feet of sandstone 10 feet above the bottom of the cut and 20 feet of shale below it to near drainage level. On the left, at the head of this fork, 3 miles up, a closed opening shows a coal bed 4½ to 5 feet thick under 10 feet of shales. This is said to have been recognized as of the Flag bed although its altitude, 1,405, is above even that which the observed rise of the strata along the creek leads one to expect, involving a rate from the Smith opening of about 200 feet per mile. Assuming it to be the Flag bed, the high hill in which it is opened appears to be a center from which strata dip in all directions. On the left, at the mouth of a branch of Lot's creek opposite Trace Fork, the Fire-clay coal is opened 32 inches thick with 4 inches of shale under sandstone above it, altitude 885. On the left, by the road,

a quarter mile above Trace Fork, the following section was taken:

Fire Clay Coal.

Massive sandstone	20 ft.
Shale, containing coal	2 ft.
Shale	2 ft.
Coal	36"

On the right, 1¼ miles above Trace Fork, a 12-yard entry into the Fire-clay coal gives a thickness of coal of 38 inches at (exact) altitude 889. For other openings into this and its rider along this creek, reference is made to Bulletin No. 11, pages 93 and 94. Under the D. Grigsby opening is 20 feet of thin bedded sandstone, then 10 feet of shale on one foot of coal, then 3 feet of massive sandstone to the creek. This coal dips into the creek 10 yards down it. The upper opening, on the right, 2½ miles up, has now a long exposure above the creek from which the following section was obtained, except that, the cannel coal being now covered, its earlier measurement is repeated.

	Massive sandstone	15 ft.
Rider	Coal	25"
	Shale	8"
	Coal	25"
	Shale	10 ft.
	Sandstone	0 to 5 ft.
Fire Clay Coal	Coal	24"
	Slate	2"
	Cannel coal	22"

Altitude, 900.

On the left, about two miles above Trace Fork, the Hazard bed with 3-inch parting separating two seams of coal each 22 inches thick, lies at altitude 1,185. On the left, opposite the mouth of Elk Fork, 4½ miles above Trace Fork, the following section is exposed:

Massive sandstone	15 ft.
Coal.	
Interval	10 ft.
Thin coal.	
Parting	1 ft.
Thin coal.	
Interval	20 ft.
Sandstone	5 ft.
Coal	27"
Shale and S. S. to creek	20 ft.

Altitude, 965.

Whether the 27 inches of coal is of the Fire-clay bed or its rider, is doubtful, but the probability seems to be that both beds are represented in the several coals shown.

Elk Fork.

On the right, 4½ miles above Trace Fork.
Altitude of mouth, 945.

Nothing new has been found on this fork, but the 54 inches of clean coal on the upper right fork given in Bulletin No. 11, page 95, is evidently under later developments, too high for the Hazard bed and is of the Flag bed. Its correct altitude is 1,325.

Clear Fork.

On the left, 5 miles above Trace Fork.

On a branch on the left, ⅜ mile up Clear Fork, on the left, ¼ mile up it, Sylvester Grigsby has an entry into the Flag coal at altitude 1,305, giving 58 inches of clean coal under 15 feet of sandstone—the lower third thin bedded. This is on a good bench and the top of the cliff rock on which is the Hazard bed, shows 40 feet below. On the left of Clear Fork, 1⅜ miles up it, Washington Martin has a 5-yard entry into the Flag coal at altitude 1,270, the coal having 10 feet of sandstone above it, is 60 inches thick, the top 4 inches rather shelly, the rest good block coal, the under half hard. A broad bench lies about 40 feet below. On the right of a left branch, 1½ miles up Clear Fork and ⅛ mile up the branch, an old prospect into the Hazard bed on this same broad

bench at altitude 1,220, found evidently only thin coal, now covered. On the right, ¼ mile up the branch, Washington Martin has a 4-yard entry with 60 inches of coal which has here as roof 8 feet of clay shale in place of sandstone. On the right of a left branch, 1¾ miles up Clear Fork and on the left of a left branch 100 yards beyond, Benjamin Stacey has 10-yard and 6-yard entries with the following sections:

Flag Coal.

Shale	3 ft.
Massive sandstone	2 ft.
Coal	63"
Bituminous shale	1"

Altitude, 1,310.

Shale	8 ft.
Coal	20"
Mother coal	¼"
Coal	46"

Altitude, 1,315.

A 20-foot cliff is prominent about 40 feet above this bed which lies here 15 to 20 feet above a bench.

On the left, by the road, a half mile above Clear Fork, the highest coal of those shown opposite the mouth of Elk Fork, 60 feet above it, has 2 feet of coal including two thin partings, under 5 feet of sandstone. On a right branch a mile above Clear Fork, a flag stone quarry on the left at the mouth of the branch, lies at altitude 1,185, while farther up the branch a bench at 1,205 marks the place of the Haddix coal. A second bench and spring by the path beyond, seem to show the location of the bed between the Haddix and Hazard at altitude 1,270. At the branch a half mile up it the following is opened in a 10-yard entry:

Flag Coal.

Sandstone	15 ft.
Shelly coal	3"
Rich block coal	23"
Hard block coal	30"
Slaty coal	6"

Altitude, 1,345.

Besides these variations in the coal there is from 0 to 6 inches of slaty coal 2 feet up from the bottom.

On the left of a right hollow just below Cordia P. O., 1¾ miles above Clear Fork, B. W. Combs has an 8-yard wet entry into the Flag bed at altitude 1,390, giving 53 inches of coal under 2 feet of massive sandstone with thinner bedded sandstone above. On the way to this entry an uprooted tree showed a considerable stain of the Hazard bed at 1,345. On the point of the hill to the left by the Combs house, the following section was obtained:

Bench	1,150
Shaly sandstone....(5 feet)	1,135
Mostly shaly sandstone.	
Thin coal stain	1,105
Mostly shaly sandstone with iron ore.	
Black slate	1,090
Shaly sandstone.	
Bastard limestone ....(1 foot)	
Thin coal	1,060
Shaly S. S. and shale.	
Coal, reported 20″	1,035
Shale ....(8 feet)	
Coal, reported 20″	1,025
Shale ....(7 feet)	
Coal, reported 30″	1,015
Fire clay ....(3 feet)	
Creek at Cordia	995

The three lower coals probably represent again the fire-clay coal and its rider.

DICKSON BRANCH.

On the right, ½ mile above Cordia.

On the left of the branch, ⅛ mile up it and 15 feet above it, a two-yard entry into what is probably the upper seam of the rider, gives 31 inches of coal at altitude 1,050, covered by 4 feet of shale with calcareous concretions under 10 feet of shaly sandstone. At the branch, ½ mile up, is the following:

Black slate	10 ft.
Coal	8"
Shale	5 ft.
Coal.	
Shale with coal	10 ft.
Shale to creek at 1,100	15 ft.

Such a thickness of black slate as is exposed at the top seems to be entirely out of place, but it is at a level where exposures are few. Above this section, on the left, Alexander Smith has a four-yard wet entry into the Flag coal at altitude 1,385. There is somewhat over 4½ feet of coal here, the bottom half a hard block with a streak of bony coal on top of it. The roof is a waving sandstone with shale filling the rolls so that the coal has a level top, differing in that respect from the Sang Fork of Jake Fork coal. A bench lies about 60 feet below this coal. Coal 18 inches thick containing considerable pyrites, is reported to have been taken from the creek, ⅛ mile below Ehe P. O., at the junction of Young's and Kelly Fork. It is probably the middle one of the three seams at Cordia and the main Fire-clay coal may be assumed to lie at Ehe at altitude 1,050, 10 feet under the creek.

YOUNG'S FORK.

On the left, 3¾ miles above Clear Fork.
Altitude of mouth, 1,060.

On the left, ¼ mile up this fork, the upper one of the three rider seams is but just above the creek, 26 inches of coal at altitude 1,075, lying on black slate and under 8 feet of shale covered by 25 feet of sandstone and shale.

BUCK BRANCH.

On the left, ½ mile above Ehe.

At the branch, ¾ mile up it, Mansard Young has an opening into the Flag coal at altitude 1,385, reported to be 4½ feet thick without parting. The 3 feet of coal visible when visited has 2 inches of bone coal 6 inches

from the top. Upon the coal is 6 feet of shaly sandstone and then 20 feet of massive sandstone..

On the right of the left branch which the road to Beaver creek follows, 2 miles from Ehe and ¼ mile up the branch, Reese Young has a 12-yard entry with the following section:

Flag Coal.	
Massive sandstone	10 ft.
Covered	15 ft.
Sandstone roof.	
Coal	3″
Bony coal	4″
Coal	6″
Hard, block coal	38″
Altitude, 1,420.	

The bony coal is dull black and heavy, but gives a black streak and is said to burn to fine ash, but the next Flag coal opening shows an impending parting here. From the right branch, a quarter mile up from the Beaver creek road, and again 2 miles from Ehe on John Young land, coal has been raised from the creek said to be 3 feet or more thick, half as much being in sight when visited. Its altitude is 1,340. At a point 5 feet lower in the branch a part of the bed has broken off and lies at a steep pitch showing about 2 feet of coal, with possibly more washed away and with black slate and shale under it which seems to correspond with a parting in the bed on Elk Lick Fork and is probably one here. Up the steep branch, at altitude 1,370, is an old prospect into coal said to be thin, under a 20-foot cliff making sandstone. On this sandstone which gives rise to a broad bench here at altitude 1,390 is the place of the Hazard coal. The Flag coal is opened in an entry directly to the left of the coal in the creek, nearly vertically over it, and with the following section:

Flag Coal.	
Sandstone	8 ft.
Block coal	14″
Shale	13″
Block coal	44″
Black slate.	
Altitude, 1,440.	

An inch of coal 2 inches from the top is slightly bony. The interval between the upper and lower of these John Young coals corresponds with that found between the Haddix and Hazard beds elsewhere and no other thick coals have been found heretofore in this region 100 feet apart. The inference however, that these openings are of the Haddix and Hazard beds is over-weighted by the several openings from the indisputable Flag coal at Cordia to the upper opening here, to which may be added the Clear Fork openings, resemblance being too marked to warrant other correlation. Cliffs and benches are uncertain guides, yet in this case, if any, they may be taken as assurance that the upper opening is of the Flag coal. The lower opening then, unless there has been such a change of interval as may be regarded as out of the question, is half way between the Haddix and Hazard beds corresponding with the Sang Fork of Jake Fork coal if the deduction advanced as to that correlation is correct. The bed is more fully developed in the next description and may appropriately be called the "Young" coal.

ELK LICK FORK.

On the right, 1¼ miles up Young Fork.
Altitude of mouth, 1,140.

On the right, ¾ mile up this fork, the 20-foot sandstone cliff shows again at altitude 1,345 to 1,365. A mile up, at William Young's, the Young bed has the following section, as measured along the creek bed where it is almost fully exposed:

Young Coal.

Shaly sandstone.	
Coal	31"
Black slate	4"
Shale	6"
Black slate	2"
Clay	2"
Coal	14"

Altitude, 1,325.

The thickness given of each coal may be slightly in error.

KELLY FORK.

On the right at Ehe, 3¾ miles above Clear Fork.

Apparently the upper of the three Fire-clay coals goes below drainage, ¼ mile up this fork, where it shows a foot thick with no bottom found: Altitude 1,075. At Thomas Kelly's, a mile up, thin coals appear at altitudes 1,185 (above his house) and 1,200 under his flagstone quarry, which latter is at 1,255, with shales and shaly sandstones between. The quarry is probably close under the Haddix coal as on the branch below Cordia. On the right, 1⅛ miles up, Benjamin Everidge has opened the Young bed about at the same level as it was found on Elk Lick Fork, with following section:

Young Coal.

Sandstone	5 ft.
Shale	5 ft.
Hard, block coal	29"
Shale	3"
Coal	1"
Shale	1"
Very hard, block coal	7"

Altitude, 1,325.

This opening is on a broad bench; the height and character of the bed are the main factors in the correlation.

Asuming the Fire-clay coal to be at altitude 1,050 at Ehe and to rise uniformly to its upper opening on Trace Fork of Irishman creek, it should be at altitude 1,065 at this opening, and on this supposition the opening might be of either the Young or Hazard bed, but the findings on the head of Yellow creek, a half mile south, lead to the conclusion that there is an anticline between Kelly Fork and Carr Fork waters, slight at the head of Irishman creek, but with crest running nearly level along the dividing ridge, amounting to 100 feet rise at the head of Yellow creek. This makes a rather rapid rise of strata toward Yellow creek and also puts the fire-clay coal nearer to the Everidge opening than if the rate were uniform to Irishman creek and the opening is therefore concluded to be of the Young coal. From a right branch 2 miles from Ehe and ¼ mile up it, coal partly splint, has

been taken said to be 2 feet thick. Its altitude is 1,415 and it also is probably of the Young bed, very likely the upper seam with more coal under what was supposed to be the floor.

On the left of the creek and right of the road, 2¼ miles up, an opening, fallen in, shows a thick bed reported to have 3 feet of coal at the top, a parting, and 3 feet more at the bottom including two partings, one of them thick. This report bears considerable resemblance to the bed section at the Everidge opening, but its altitude of 1,400 seems to place it in the Haddix bed. On the left, 2½ miles above Ehe, the same bed at about the same height has been opened, but was closed when visited and only 2½ feet of coal was seen of an apparently thick bed covered by 15 feet shale. On the right, 3 miles above Ehe, an apparently thin coal was found at altitude 1,505, which may be of either the Hazard or Flag beds and there is a broad bench at 1,585 supposed to be about 50 feet under the Hindman coal. With the hill over this bed rising here some 300 to 400 feet higher, a good working area in it is assured and its 8 to 10 feet of coal should be prospected for at some point nearer than the head of Irishman creek, where it has been found.

UPPER SECOND CREEK.

The Fire-clay coal at the mouth of this stream is, as at the mouth of Lot's creek, about 60 feet above the river. The bed rises slightly up stream but is only 15 feet above drainage, 1½ miles up. Following are bed sections:

ENTRY ON THE RIGHT, ¾ MILES UP.

Fire Clay Coal.

Shale	8 ft.
Coal	2"
Shale	2 ft.
Coal	42"
Flint clay	5"+
Coal	5"+

Altitude, 895.

JAMES PAYSON'S 20-YARD ENTRY,

ON THE RIGHT, 1½ MILES UP.

Fire Clay Coal.

Shaly sandstone	10 ft.
Coal	41"
Flint clay	4"

Altitude, 905.

In the first the fire-clay parting has an uneven, knobby surface which may give a variation of an inch in the thickness of the coal above it and of the parting, according as measurement is from the top of a knob or not. The under coal is given approximately at 5 inches. In the upper entry, the middle one of a group of three, the coal measures 41 inches at the mouth and face and 43 inches at the mouth of the entry next above. The fire-clay forms the floor of the entries with probably more coal below. This bed appears not to have been opened on this creek above this group of entries.

COMBS FORK. ON THE LEFT, 2½ MILES UP.

On the left of this fork, 2½ miles up it, beside the bridle path to Elk fork is a 5-yard wet entry from which the following was obtained:

Flag Coal.

Sandstone	5 ft.
Coal	37"
Clay	6"

Altitude, 1,280.

The depth of the entrance cutting admits of a few inches more coal below the clay which was found to be over 6 inches thick, but if there is any coal below, it can hardly be of much importance.

On the left of the main creek, ¾ mile up from the mouth of Combs fork, and by a path crossing to the latter, an old prospect gives the height of the Flag coal as 1,250.

On the right, 1¼ miles above Combs fork,and on the left, 1½ miles up, the Hazard coal gives the following:

Ben Stacey—Wet entry—On right.

James Stacey—5-yard entry—On left.

Hazard Coal.

Ben Stacey		James Stacey	
Slipped coal.			
Clay.		Sandstone	7 ft.
Coal	8"	Block coal	40"
Shale	8"	Altitude, 1,235.	
Coal	12"+		
Shale	17"		
Coal	37"		
Altitude, 1220.			

The lowest two feet of this coal, like much of the Flag coal at bottom, is a hard block. The higher seams of the coal on the right were not in condition for exact measurement; their entire absence on the left is noteworthy. Fifty feet above the Benjamin Stacey entry is a prospect into the Flag coal, partly covered, apparently about 4 feet thick. Altitude 1,270.

James Stacey also has the Flag bed opened in a wet entry on the left in front of his house, 1¾ miles above Combs fork, in which a bed 4½ feet or more thick is evident under 8 feet of shale. About 3 feet of coal at the top was visible. Like the preceding it lies 50 feet above the Hazard bed; its altitude is 1,285.

WALKER BRANCH.

The uniformity of the Fire-clay coal in this region made unnecessary a second visit to this branch. The 38 inches top coal, 5 inches fire-clay and coal below, generally not mined and therefore seldom exposed for measurement, seems to be standard for this vicinity.

On the left at the head of this branch is the following: (An opening is said to have been made into the Flag coal directly above it.)

Hazard Coal.

Five-yard wet entry.

Shaly sandstone.	
Block coal	39"
Hard coal	16"
Altitude, 1,240.	

A coal stain on top of the right toward Hazard, at altitude 1,465, is the only sign of a bed above the Hindman yet seen by the writer north of the Kentucky river.

HAZARD AND VICINITY.

A section of the Fire-clay coal half a mile below Hazard (taken from Bulletin No. 11, page 96) and analysis is:

Fire Clay Coal.

Shale and shaly S. S.	
Coal	34"
Flint clay	5"
Coal	4"
Bone coal	1"
Shale	11"
Coal	4"

Analysis.

Moisture	1.50
Volatile matter	33.50
Fixed carbon	61.20
Ash	3.80
Sulphur	0.794

Specific Gravity, 1.287.

Centrally located in the town of Hazard, a quarter mile up the small branch with mouth by the river bridge, the Speak mine is worked by the Speak brothers in the Fire-clay bed at altitude 930, the river being there at about 840. The coal when measured, some 50 yards in, is 37 inches thick, including 2 inches of slaty coal at the bottom which sticks to the floor and in hand-mining is left. The whole seam is said to range in the mine from 37 to 46 inches. At the mouth 15 feet of shale covers the coal, but the roof is fairly good, doubtless becoming sandstone. Besides filling a large part of the local demand for coal, some is shipped by rail after hauling across the river in wagons. One coal-cutting machine is used, operated by compressed air.

On the right, at the head of this branch, the Hazard bed has been opened by a prospect, and coal about 39 inches thick is in sight, at altitude 1,230, under 7 feet of shale. Another seam of the bed beneath the 39 inches is quite possible.

On the branch at the upper end of town, ¾ mile up, three entries give each 38 inches of coal, including about 6 inches of slaty coal at bottom. The characteristic fire-clay is below that. A fourth 5-yard entry on the right has but 30 inches of coal mined. Altitude 940.

At the sharp bend of the river, 1¼ miles above Hazard an entry has been made into the same bed on the right, ⅛ mile up the branch there. The good coal is 34 inches thick, the floor a black slate rather than slaty coal, roof a cliff sandstone of 40 feet thickness, which has permitted setting of posts 20 feet apart in each direction without perceptible strain.

Higher coals were searched for on this branch, but nothing satisfactory found, apparently. Nearly the whole face of the hill on the right seems to have broken and slipped.

At the mouth of this branch the following section, taken from Bulletin No. 11, was obtained giving the heights of the Whitesburg and Fire-clay coals as 15 and 90 feet, respectively, above the river, which here is about 845 feet above tide instead of 925 as there assumed.

Fire Clay Coal.

	Sandstone	20 ft.
Fire Clay Coal	Coal	35″
	Flint fire clay	7″
	Coal	3″
	Clay.	
	Sandstone	60 ft.
	Shale	5 ft.
	Black slate	5 ft.
Whitesburg Coal	Coal (12 partings)	40″
	River, 845.	

The Kentucky Jewel Coal Company is preparing for an operation on and below Raccoon creek, 2 miles above Hazard. The intention seems to be to mine at present only the Flag coal, an old entry into the Fire-clay coal on the river front not having been reopened nor other work on that bed begun.

Above this coal an old flag-stone quarry, 230 feet higher, appears to be at the base of the Haddix coal. The Flag coal entries, reached via line for incline from

the river frontage, are on the left, perhaps a half mile up Raccoon creek, and are 365 feet, by barometer, above the fire-clay coal opening. The northern of two well begun entries gives the following section:

Flag Coal.

Sandstone	5 ft.
Block coal	30″
Bony coal	3″
Block coal	15″
Shale	3″
Coal	4″

The bony coal may perhaps be classed as poor splint coal.

A broad bench at the top of the proposed incline, 40 feet below this coal, shows the place of the Hazard coal.

For 2½ miles above Hazard reference is made to the section given in Bulletin No. 11, page 98, showing Whitesburg, Fire-clay and rider and probable Hazard coals, and an analysis of the latter: Altitudes given there are again about 80 feet too high.

GREGORY BRANCH.

The Raccoon Coal Company is operating 3½ miles above Hazard to a small, but increasing extent on the Fire-clay coal on the right of this branch at its mouth, and is building an incline to bring the Flag coal to the same point.

The main Fire-clay coal opening is about 80 feet above the track and at altitude 960. It was started in the point of a hill and runs rather across the point. The coal at entrance is but about 6 inches above and below the 6 inches of parting, and is some 6 to 8 feet above the normal level of the bed. At 20 yards in, where normal level is reached, the top coal is 40 inches thick, which is, perhaps, the average thickness in the mine: Its maximum is said to be 46 inches.

The coal seems to be in great demand at a good price, in spite of the fact that it is much broken up in the long chute from mine to railroad level. Following is an anlysis of the coal as obtained at the mine: Analysis by James A. Gibbony.

Analysis.

Water	1.52
Volatile matter	39.06
Fixed carbon	55.78
Ash	3.64
	100.00
Sulphur	0.634

The Flag coal is opened fronting the river near to the head of the proposed incline 375 feet above the Fire-clay coal: Altitude, 1,335. Barely underground it gives 47 inches of coal, with 8 inches of shale and then 8 feet of sandstone above it.

On the left of a left branch, ¼ mile up Gregory and ⅛ mile up the branch, the following section was obtained at the mouth of a wet entry:

Fire Clay Coal.

Sandstone	6 ft.
Coal	33"
Flint clay parting.	
Fire clay.	

Altitude, 950.

The rider shows here about 18 inches of coal, at altitude 970.

On the right at the head of this branch, an old opening showed in the dump blocks of heavy splint coal and some block coal. The bed may be 3 feet thick, its altitude is 1,295, making it the Hazard bed.

On the right, ½ mile up Gregory, the following section was obtained:

Gap-level of Hindman coal	1,430
Prospect: Apparently 3 to 4 feet of coal, largely splint, which weathers into small thin plates like black slate	1,365
(In this report this bed is given the name of "Francis.")	
Flag coal prospect: about 5 feet without parting, under 5 feet shale	1,310
Hazard 3-yard entry: Coal 43 inches, under 5 feet of shaly sandstone	1,260
Broad bench (Young coal?)	1,225
Prospect: Coal 17 inches under 5 feet shale	1,025
Fire clay coal level	950

On the left nearly opposite these the following was obtained at a 5-yard entry:

Fire Clay Coal.

Sandstone	10 ft.
Shale	2 ft.
Coal	36″
Flint clay	3″
Coal	4″

Altitude, 950.

In the point of hill on between the forks, ¾ mile up, 30 feet of shaly sandstone is exposed at altitude 1,035 over coal which is probably the 17 inches coal at 1,025 of the preceding section. Certainly the continuation of thin lamination below the Haddix bed is shown.

On the left, a mile up, the Hazard bed has the following section:

Hazard Coal.

Shale	5 ft.
Coal	4″
Shale	6″
Coal	5″
Shale	6″
Coal	2″
Shale	2″
Coal	9″
Shale	6″
Coal	36″
Fire-clay.	

Altitude, 1,215.

And to the right above it the Flag coal this:

Flag Coal.

Shale	3 ft.
Coal	53″
Shale	3″
Coal	6″

Altitude, 1,275.

Other openings into the Fire-clay coal by the road above Gregory branch are given in Bulletin No. 11, pages 99 and 100.

BEAR BRANCH.

Four and one-half miles above Hazard: Altitude of mouth 870.

On the left, ¾ mile up this branch, is a 12-yard entry with the following section:

Flag (?) Coal.

Shale	10 ft.
Coal	2″
Shale	4″
Block coal	8″
Splint coal	15″
Block coal	8″
Hard block coal	23″

Altitude, 1,360.

The bottom coal has an inch of bone which appears not to be continuous.

The ascertained height of this bed above the Fire-clay coal, and its thickness, are indicative of the Flag coal, but the splint coal in it, apparently perfectly good, weathers into small thin fragments like black slate, to a degree never seen by the writer elsewhere than here and in the coal found above the Flag on Gregory branch. A possible error of 40 feet in altitude would throw this opening into the higher bed.

On the left, by the road, 4¾ miles above Hazard, the following was obtained at the mouth of a wet entry:

Fire-clay Coal.

Sandstone.	
Shale	3 ft.
Coal	1″
Shale	3″
Coal	39″
Flint clay	3″
Bottom (?) clay.	

Altitude, 975.

On the left, by the road, 5¼ miles above Hazard, an exposure gives:

Whitesburg Coal.

Sandstone	40 ft.
Shale	3 ft.
Black slate	5 ft.
Coal and shale	1½ ft.
Shale	6 ft.
Coal	1½ ft.

Altitude, 920.

BUCKEYE CREEK.

Five and three-quarter miles above Hazard. Altitude of mouth, 875.

On the right of the left fork at its head, two miles from the river a 12-yard entry gives:

Flag Coal.

Sandstone	15 ft.
Shale	0 to 12"
Shelly coal	12"
Splinty coal	12"
Bony coal	1"
Hard block coal	43"

Altitude, 1,370.

The inch of bony coal is almost inseparable from the coal below, but does not seem to be very impure. The variation in thickness of shale is due to an even top to the coal and a waving sandstone above it. On removal of the coal the shale comes down, leaving a fine roof, taken advantage of here in the width of the entry driven.

CARR FORK.

Six and one-quarter miles above Hazard: Altitude of mouth 880.

On the right, a half mile up,-J. P. Combs has a wet entry with the following section:

Fire-clay Coal.

Sandstone	4 ft.
Shale	2 ft.
Coal	4"
Shale	2"
Coal	29"
Bony coal	3"
Flint clay.	
Coal (?)	

Altitude, 1,095.

The total thickness, from the two feet of shale down, is 47 inches, the flint clay is probably not over 4 inches thick, leaving 5 inches or more for coal at the bottom. The bony or slaty coal is not marketable. The roof is good, probably becoming sandstone a few yards in.

On the same property and on the right of the creek an eighth mile farther up a covered prospect indicates a good thickness of Flag coal at altitude 1,450.

ACUP BRANCH.

On the left of Carr, 1½ miles up. Altitude of mouth 895.

On the right of this branch, ¼ mile up, Sampson Combs has a wet entry giving the following section;

Fire-clay Coal.

Coal stain.	
Shale	1 ft.
Coal	5"
Sandstone	3 ft.
Shale	8 ft.
Coal	6"
Shale	1"
Coal	31"
Flint clay.	

Altitude, 1,070.

A half mile up a branch on the right, ⅜ mile up Acup, in the point of a hill on the left, an abandoned opening shows a possible 4 feet of coal covered, under about 3 feet of shale and 20 inches of coal over that. Its altitude, 1,480 is high for the Flag coal and low for the one above it.

MILLSEAT BRANCH.

On the right, ½ mile up Acup.

The same bed is opened on the right at the head of this branch, ½ mile up it, with the following section at the mouth of a 3-yard wet entry:

Flag (?) Coal.

Sandstone.	
Coal	19"
Shale	10"
Coal	43"

Altitude, 1,465.

Both openings are on Edward Combs' land. A prominent bench lies 60 feet higher.

On the left at creek level 5/8 mile up the following is exposed in a cliff:

Whitesburg Coal.	
Massive sandstone.	
Shale	20 ft.
Coal	6"
Bone coal	5"
Coal	7"
Coal and shale	3 ft.
Altitude, 1,015.	

The coal and shale at the bottom alternate too frequently for measurement.

On the right, 3/4 mile up and again 7/8 mile up, Roland Combs has 8-yard and 15-yard entries into the Fire-clay coal, the latter at creek level, and both at altitude 1,060, which give sections as follows:

Fire-clay Coal. 8-yard entry.	
Sandstone.	
Shale	1 ft.
Coal	2"
Shale	1"
Coal	5"
Shale	2"
Coal	30"
Flint clay	5"
Coal	6"
Cannel coal	5"
Coal	7"

Fire-clay Coal. 15-yard entry.	
Sandstone	15 ft.
Shale	6"
Coal	30"
Flint clay	7"
Cannel coal	7"
Black slate or coal.	

The floor of the upper entry, in water, could not be ascertained fully. The flint fire-clay here is black instead

of the usual brown, and may easily be mistaken for black slate, or for coal if not inspected closely. The cannel coal appears good.

On the right of a left branch one mile up, close the Roland Combs house, in the branch and 15 feet above Acup branch the Fire-clay coal rider has the following section:

Fire-clay Coal Rider.

Sandstone	20 ft.
Shale	4 ft.
Coal	27"
Bituminous slate	5"
Slaty coal	9"

Altitude, 1,085.

The bottom coal, measured in water with difficulty, may be slightly more or less than 10 inches. The slate parting closely resembles the black fire-clay parting of the lower bed. So far as known such parting does not appear elsewhere in this bed, but farther up on Carr and up the river it is often seen as float, washed presumably from the Fire-clay coal, but possibly from its rider.

On the left, a quarter mile up the right fork of Acup and two miles from Carr a prospect on land of Combs heirs into the Flag bed at altitude 1,425 gives 58 inches of rich hard block coal under 4 feet of shale covered by sandstone.

On the right branch, 2⅜ miles up Carr, on the right, ⅛ mile up the branch, Benjamin Combs, has a 4-yard entry of the following section:

Fire-clay Coal.

Shale with calcareous concretions	4 ft.
Coal	6"
Shale	1"
Coal	8"
Shale with coal	24"
Coal	29"
Flint fire clay	6"
Shale	8"

Altitude, 1,080.

The bottom shale, which may be thicker than 8 inches, possibly overlies more coal of this bed. The roof is good, indicating a change to sandstone. Five other entries or prospects into this bed have been made on this property all within a quarter of a mile and all closed.

On the right of a left branch, 2½ miles up Carr, by his house, Washington Combs has a 12-yard wet entry with the section following:

Fire-clay Coal.

Sandstone	8 ft.
Shale	6 ft.
Coal	39″
Flint clay	8″
Coal	7″
Black slate floor.	

Altitude, 1,070.

More coal was reported below the floor, which was felt but not seen. The bottom coal was not measured exactly.

On the right, 3 miles up Carr, a 12-yard entry, and on the left a closed entry, 3¼ miles up, both of Robert Combs, gives the Fire-clay coal and its rider, or at least a part of the rider. The altitude of the bottom coal of each is 1,050.

Fire-clay Coal.

Sandy shale	10 ft.
Coal	38″
Flint clay	3″
Coal	5″
Black slate	3″
Clay.	

Fire-clay Rider

	Shale	4 ft.
	Coal	2 ft.
	Shale	1½ ft.
Rider.	Coal	8″
Rider.	Shale	2″
Rider.	Coal	3″
	Shale	8 ft.
	Fire-clay coal.	

WHITE OAK BRANCH.—On the left, 3½ miles up Carr. Altitude of mouth, 915.

On the right of this branch, 5/8 mile up it, is 14 inches of coal of the Whitesburg bed, probably at altitude 1,040, with 2 feet of shale and then sandstone, mostly thin bedded, to the bed above it.

On the right of the branch, 3/4 mile up and 10 feet above it, Short Gardner has a 7-yard wet entry in 38 inches of coal, with a hard floor and sandy shale roof; its altitude is 1,065.

SCUDDY BRANCH.—On the right, 4 miles up Carr. Altitude of mouth, 920.

In the branch a half mile up is 11 inches of coal under 8 feet of shale at altitude 1,040 and on the right, 25 feet higher, 6 inches of coal on 5 feet of fire-clay and under 1½ feet of shale and a 25-foot sandstone cliff. This may be the beginning of a bed, 100 feet under the Fire-clay coal, which assumes considerable importance farther up Carr, but there it has thick shale over, as well as under it.

On the left, 3/4 mile and one mile up, John Mullins has 8-yard and 12-yard entries into the Fire-clay coal, at altitudes 1,140 and 1,150 which give the following:

At 1,140.		At 1,150.	
Sandstone	1 ft.	Sandstone	5 ft.
Shaly sandstone	1 ft.	Coal	30″
Coal	37″	Flint clay	4″
Flint clay	5″	Coal	13″
Coal	5″	Fire clay.	
Black slate	4″	Sandstone.	
Coal	4″		

The bottom coal at the higher entry has a knife-edge of black slate at the face decreased from 3 inches between two 6-inch seams of coal at the mouth of the entry.

On the left at the forks, 1½ miles up, at stream level, on John Combs' land, is the following:

Shale	10 ft.
Coal	7″
Shale	6″
Coal	6″
Shale	3″
Coal	10″

Altitude, 1,280.

By the house on the right, some 50 feet higher, an opening has been made into what is probably the Haddix bed, but the prospect is wholly closed.

On a left branch, 4½ miles up Carr, on the left, ⅛ mile up it, J. P. Combs has a 5-yard entry with the following section:

Fire-clay Coal.

Coal	36″
Bone coal	3″
Coal	4″
Flint clay	3″
Coal	3″
Black slate	7″
Clay.	

Altitude, 1,060.

Only the 36 inches at the top is mined.

GEORGES BRANCH.—On the right, 4½ miles up Carr. Altitude of mouth, 925.

On the left of a left branch, ¼ mile up George branch, ⅛ mile up the left branch, J. J. Mullins has a wet entry giving 36 inches of coal at its mouth. An adjacent entry formerly gave to the writer 39 inches of coal with 6 inches of black jack and black slate below.

At ¾ mile up Allen Sumner has a wet entry on the left at altitude 1,145, and on the left of a right branch, ¼ mile up it, Jesse Combs has an 8-yard entry at altitude 1,155, both in the Fire-clay coal. Their sections are:

Sumner.

Sandstone	5 ft.
Coal	41″
Flint clay	5 to 6″
Coal.	

Combs.

Sandstone	10 ft.
Coal	21″
Flint clay	6″
Coal	11″

In each of these the fire-clay parting is black, resembling slate. In the Sumner entry the roof is noticeably good. In the Combs entry the massive sandstone is uneven at bottom but the coal follows its irregularities. On one side of the entry near the top a thin sandstone parting appears, which runs down towards the middle of the bed and apparently culminates and ends in a 6-inch ball at the face. This freakish sandstone and great re-

duction of the upper coal are not likely to extend far. The measurement given are from the mouth of the entry. At the face the parting is about half as thick, but the effective coal is reduced by a little coal sticking to the fire-clay.

A mile up to the forks of the creek, and 1/4 mile up the left fork, 15 feet above it, an 8-yard entry on the left, and at water level and a 2-yard entry on the right, both in the Fire-clay coal at altitude 1,200, give 33 inches of coal on 5 to 8 inches of black flint fire-clay with coal below, 4 inches thick in the latter entry. Five feet of sandstone shows above them.

On the left of the right fork, 1/4 mile up it, 30 feet above stream, and on the right, 1/2 mile up, 10 feet high, in a 20-yard entry of Robert Combs, each at altitude 1,210, the following sections were taken:

On Left.		On Right.	
Sandstone	5 ft.	Sandstone	15 ft.
Coal	44" (?)	Coal	40"(?)
Flint clay.		Flint clay	6"
Shale	30 ft.	Coal	5"
		Clay	1 ft.
		Sandstone.	

It is possible that a black jack of some 4 inches thickness lying on the flint fire-clay is included as coal in the foregoing.

The rockhouse on the right just beyond the Combs entry, 3 feet above the stream has about the same section as the entry.

MONTGOMERY BRANCH.—On the right, 5 3/8 miles up Carr: Altitude of mouth, 935.

From this branch at its mouth a cliff rises of some 30 feet of shale, with 40 to 50 feet of sandstone on top of that, carrying the measures nearly to the thin coal 100 feet below the Fire-clay coal.

In a left branch, a mile up Montgomery, 9 inches of coal at altitude 1,030 (the 6-inch coal of Scuddy) is covered by 5 feet of shaly and 20 feet of more massive sandstone.

On the right, 1/4 mile up the branch, on D. Combs' land, is a prospect into the Fire-clay coal, fallen in, but with 3 feet of coal still visible under 15 feet of shale; its

altitude 1,115. In the first right drain below, a prospect revealed the following:

Fire-clay Coal Rider.	
Shaly sandstone	5 ft.
Coal	6″
Shale	1″
Coal	7″
Shale	3″
Coal	14″
Shale	10″
Coal	9″
Shale	2″
Coal	5″

Altitude, 1,140.

A total of 45 inches of coal in a bed of 57 inches total thickness.

On the right, 1½ miles up, Judge Combs has a prospect into the Fire-clay coal at altitude 1,145, its section given below approximately, and also a wet entry on the left, altitude 1,160, ¼ mile up the left fork, which enters the main creek at his house, 1¾ miles from Carr.

Prospect.		Entry.	
Shale	15 ft.	Shale	5 ft.
Coal	44″	Coal	58″
Flint clay	4″	Flint clay	2″
Coal	5″	Coal	2″

The flint fire-clay is black and possibly should include 3 or 4 inches of what is given as coal above it.

On the right, ⅞ mile up this left fork the top seams and parting of the rider are exposed 25 feet above the Fire-clay coal.

On the left, at the forks of the left fork, 1 mile up, 40 inches of the main seam of the Fire-clay coal was seen, but not the bottom.

Under it is 4 inches of flint fire-clay and below that 3 inches of black slate. Five feet of shale covers the bed: Its altitude here is 1,265.

On the right fork, or main creek, on a right branch, 2 miles from Carr, on the left ⅛ mile up the branch, Robert Summers has an opening as given below: With it is given the section at a wet entry on the left, ¼ mile

up and 55 feet above the right fork, which is 2½ miles from Carr. Both are of the Fire-clay coal bed.

Summers.

Shale	10 ft.
Coal	39"
Flint clay	5"
Coal	6"

Altitude, 1,195.

Right Fork.

Sandstone	5 ft.
Coal	25"
Black Jack	3"
Flint clay	5"
Coal	7"

Altitude, 1,220.

On the right, 1½ miles up the left fork, or main creek, 4 miles from Carr, Green Combs has a 3-yard wet entry, 355 feet above the creek, into what is believed to be the Flag coal with the following section:

Flag Coal.

Sandstone	10 ft.
Coal	16"
Shale	3"
Coal	43"

Altitude, 1,695.

The bottom foot of the bed was not seen and its measurement may not be quite correct.

The correlation of the bed is on the assumption that the rise of strata continues up Montgomery branch from the last Fire-clay coal opening to this point. There appears a further slight continuation to openings of this same high bed on the heads of Bull creek, but the barometer was too inaccurate for certainty. The correlation is strengthened by the character of the bed and its roof.

The ridge northwest of Bull creek and around its head (as well as down on the north of Big branch past the head of Georges branch) is broad at the top forming what is known as "Flatwoods." Between the mouth of Bull creek and the river northwest of it, this unusual topography is principally due to the excessive hardness of the 20 to 30 feet of well-known cliff rock underlying the Hazard coal, and it is difficult to believe that the same rock is not the prime cause at the head of Montgomery branch. If this were the case, and to make the stratification and topography conformable to that at the river, the Flag bed should be 100 feet lower than the Green

Combs coal, which would make the latter of the Hindman bed. This bed has been opened in the river ridge and presents its usual characteristics of extremely thick coal under abominable roof, wholly different from the Green Combs and heads of Bull creek openings. In this connection is noted a very hard sandstone at the gap between Bull creek and Defeated branch directly under what is assumed to be the Hazard coal and 65 feet under one of these Flag coal openings.

On the right of the left fork above Green Combs', 4½ miles from Carr, Harrison Banks has a nearly closed entry into the (probable) Haddix bed giving about 34 inches of coal under 8 feet of shale.

STACEY BRANCH.—On the left, 5½ miles up Carr: Altitude of mouth, 935.

In a drain on the left, ⅛ mile up, two covered prospects in coal apparently thick enough to work are probably of the Fire-clay coal; their altitude 1,095 and 1,100. They serve to show an up stream dip to the wet entry on the right, some 20 feet above the branch, which has the following section:

Fire-clay Coal.

Rough sandstone	5 ft.
Coal	44"
Flint clay.	
Coal.	

Altitude, 1,045.

Neither the bottom coal nor the fire-clay, which is black here, were accessible for measurement.

YELLOW CREEK.—On the left, 5¾ miles up Carr. Altitude of mouth, 940.

A quarter mile up the creek and ⅛ mile up a left drain, Samuel Combs has a 12-yard entry with the following section:

Fire-clay Coal.

Sandstone	15 ft.
Coal	41"
Flint clay	4"
Coal	9"

Altitude, 1,090.

Again the fire-clay is black, and the roof is fine. The sandstone over the entry shows no coal, but in the drain by the opening, 10 feet above it, a 4-inch seam splits into two smaller ones. A slipped stain, probably of the rider, shows 35 feet above the opening.

A covered prospect, one mile up the creek and 1/4 mile up a left branch and at its level gives the height of the Fire-clay coal, 1,085, but, a thunder storm occurring while on this branch, this is not reliable. The 40 feet under it is of thin bedded sandstones and shales with lime boulders, as exposed along the branch, and the covering, 30 feet of sandstone.

On the left, 1 1/8 miles up, the same bed shows about 38 inches of coal, without the parting near the top found in the next opening. Twenty feet of thin sandstones and shales show under the bed, and two thin coals are said to lie 10 to 20 feet above it.

On the right at the creek, 1 3/8 miles up, Addison Combs has a 10-yard entry as follows:

Fire-clay Coal.

Sandstone	15 ft.
Coal	3"
Shale	1"
Coal	32"
Flint clay	4"
Coal	7"
Fire clay	1 ft.
Shaly sandstone.	

Altitude, 1,055.

The flint fire-clay is black.

What coal there is of the rider must come within 20 to 30 feet of the fire-clay coal, for about 15 feet of sandstone is exposed over the entry and, at the mouth of a left branch 1 1/2 miles up, 40 feet of shales and thin sandstones rise from the creek at altitude 1,075. The rider must go under these.

On the right at the head of the creek, 2 1/2 miles up, is a 20-foot sandstone cliff, its base at altitude 1,435, on which probably lies the Hazard bed; the altitude of the gap to Kelly fork of Lot's creek is 1,554.

A quarter mile southeast of the gap, on a good bench, George Francis has an entry into a bed midway between

the Flag and Hindman beds, to which is here given the name of "Francis." Although the bed, as given below is not so thick as found elsewhere, it is the only known place where it is carried underground:

Francis Coal.

Sandstone cliff	30 ft.
Block coal	14"
Black slate	4"
Hard block coal	15"

Altitude, 1,570.

RED OAK (OR ROWDIE) BRANCH.—On the right, 6½ miles up Carr. Altitude of mouth, 945.

An entry into the Fire-clay coal, ½ mile up this branch, taken from Bulletin No. 11 is as follows:

Fire-clay Coal.

Sandstone	10 ft.
Shale	5 ft.
Coal	37"
Shale and flint clay	9"
Coal	10"

This seems now to be abandoned, although of good thickness.

Coal 16 inches thick runs with and in the branch for nearly a quarter mile to a left branch one mile up. Fifteen feet above this coal at altitude 1,050 to 1,070 is 5 inches more coal with 10 inches parting under 10 feet of shaly sandstone.

On the left at the forks a quarter mile up the left branch one mile from Carr, Hiram Brashear has a partly covered prospect 10 feet above the branch, from which the following was obtained:

Fire-clay Coal.

Sandstone	10 ft.
Shale	5 ft.
Coal	32"
Bone coal	4"
Flint clay	3"
Coal	7"
Black slate	2"
Bone coal	3"
Coal	6"

Altitude, 1,165.

The bone in the lower seam may be marketed, that in the upper seam must be excluded.

NEGRO BRANCH.—On the left, 6¾ miles up Carr. Altitude of mouth, 945.

On the right, ½ mile up, Noah Adams has a 5-yard entry with the following section:

Fire-clay coal.

Sandy shale	3 ft.
Coal	38″
Flint clay	6″
Coal	4″
Black slate	2″
Coal	5″
Clay.	

Altitude, 1,085.

On the right, ¾ mile up, is 25 inches of coal with one inch parting 4 inches from the top, under 10 feet of shale.

A 20-foot cliff at the head of the branch, 1¼ miles up, altitude 1,390, gives the approximate location of the Hazard coal just above it. To the right of this cliff Simon Stacey has an 8-yard entry giving the following:

Flag Coal.

Sandstone	25 ft.
Coal	12″
Shale	6″
Clay	1″
Coal	17″
Bony coal	1″
Coal	23″

Altitude, 1,470.

SASSAFRAS CREEK.—On the left, 7½ miles up Carr. Altitude of mouth, 955.

In the left fork at its mouth is a foot, or possibly more, coal under a foot of shale at altitude 1,020. From this coal to the next, given at the bottom of the following section, is mostly sandstone. This section was obtained ½ mile up the left fork in front of Manton Cornett's house:

Sandstone	8 ft.
Shale	2 ft.
Sandstone	1 ft.
Shale	3 ft.
Fire-clay coal bed	4 ft.—Altitude, 1,090.
Fire-clay	2 ft.
Sandstone	2 ft.
Shale	28 ft.
Black slate	1"
Coal	7"
Black slate	1"
Coal	6"
Fire-clay.	
Sandstone in creek.	
Altitude, 1,055.	

The following sections of the Fire-clay coal were obtained; one on the left fork 100 yards above the section just given, from the mouth of a wet entry; one on the left of the right fork, ½ mile up it: Their altitudes are 1,090 and 1,085.

Left Fork.

Sandstone.	
Shale	2 ft.
Coal	24"
Flint clay	3"
Black slate	3"
Coal	6"
Bone coal	3"
Coal	6"

Right Fork.

Sandstone	2 ft.
Coal	24"
Black jack	3"
Flint clay	4"
Coal	20"
Clay.	

The roof of the Left fork entry is broken down for about 3 yards in, and the two feet of shale at the mouth there gives place to two feet of good shaly sandstone—a change frequently noted in the roof of this bed, but nowhere else so abrupt. A closed adjacent entry shows 30 inches of top coal.

In the middle of the bottom coal of the Right fork opening is a bone coal running in thickness from nothing to 4 inches. A closed entry on the opposite side of the creek has 7 inches of coal 4 feet above the main seam, apparently a split from it and the cause of its reduced thickness.

KELLY BRANCH.—On the left, 9 miles up Carr: Altitude of mouth, 970.

The Whitesburg bed with black slate roof lies in this branch, ¾ mile up it, at altitude 1,060, its thickness not ascertained. Below and above it most of the way to the Fire-clay coal the branch is bared to thin bedded sandstone.

George Kelly has a wet entry a mile up this branch, at its level and at altitude 1,095, with section as given with the Lee Kelly section following. The latter is from a wet entry on the left of a left branch, 9¼ miles up Carr, on the left, ⅛ mile up the branch. Its altitude is 1,120.

George Kelly.

Sandstone	30 ft.
Covered	3 ft.
Coal	7"
Shaly limestone	5 ft.
Shale	2 ft.
Coal	24"
Black jack	4"
Flint clay	2"
Coal	19"
Shale in branch.	

Lee Kelly.

Sandstone.	
Shale	10 ft.
Coal	2"
Shale	4"
Coal	28"
Black jack	2"
Flint clay	3"
Coal	17"

The bottom coal of the Lee Kelly section is of somewhat doubtful measurement.

IRISHMAN CREEK.—On the right 10½ miles up Carr. Altitude of mouth, 980.

RIGHT FORK.—One half mile up Irishman creek.

On the right, ½ mile up this fork, Spencer Combs has a wet entry where the following section was taken:

Fire-clay Coal.

Sandstone.	
Shale	8 ft.
Coal	24″
Black jack	3 to 4″
Flint clay	4″
Coal	11″
Clay.	

At ¾ mile up a thin coal under massive sandstone shows by the creek, about 100 feet below the Fire-clay coal, its altitude being 1,085.

On the right of a right branch one mile up the fork and ⅛ mile up the branch, Monroe and William Kelly have a prospect into the Fire-clay bed, at altitude 1,180, in which the lower members were found but could not be measured. Over the fire-clay the black jack is 4 inches thick, with 28 inches of coal above it, covered by 3 feet of shale.

At nearly 1½ miles up, a coal about 10 inches thick goes below drainage at altitude, 1,170 as under a Grigsby Fire-clay coal opening on Lot's creek.

On the right, 1½ miles up, a prospect gives the following:

Fire-clay Coal.

Shale	2 ft.
Coal	28″
Black jack	2″
Flint clay	4″
Coal	16″

Altitude, 1,180.

At 1¾ miles a coal goes below drainage, its thickness probably not over 1½ feet including a thin black slate parting; its altitude 1,245.

On the left, two miles up, Jack Combs has an opening as follows:

Flag Coal.

Sandstone.	
Block coal	9″
Shale	2″
Block coal	42″

Altitude, 1,605.

The height of this bed above the Fire-clay coal seems to be greater here and on Negro branch than at points farther west, but the charater of the bed leaves little room for doubt in correlation. Being here but about 50 feet below the level of the gap at th ehead of the fork, and little more in the spur where opened, its mining area is very small.

TRACE FORK.—On the left of Irishman creek, ¾ mile up it: Altitude of mouth, 1,007.

SUGAR BRANCH is on the left of Trace fork, ¼ mile up it. On the right, ¼ mile up the branch, Patrick Back has a 10-yard entry of following section:

Fire-clay Coal.

Sandstone.	
Shale.	
Coal	24″
Black jack	4″
Coal	1″
Flint clay	3″
Coal	15″

Altitude, 1,120.

The inch of coal in the parting was not seen in outcrop. The upper six inches of the main coal seam is inclined to resemble cannel coal, and 2-inch blocks of such coal were found in the dump of a covered prospect on the left, ⅛ mile up the branch. Though clearly shale over the mouth of the entry, the roof is of sandstone 4 yards in. The forks of Trace are ¾ mile up it; the altitude there 1,059.

On the right, ⅛ mile up the Left fork, from a rock-house and prospect above it the following was obtained:

Sandstone	3 ft.
Shale	6″

Fire-clay Coal

Coal	23″
Black jack	3″
Flint clay	4″
Coal	17″

Altitude, 1,105.

Covered ..	10 ft.
Shaly sandstone	5 ft.
Shale ..	10 ft.
Sandstone ..	6″
Black slate	3 ft.

Whitesburg Coal.

Bright block coal	6″
Black slate	¼″
Hard, bright block coal ..	25″
Altitude, 1,075.	
Covered ..	3 ft.
Sandstone in stream.	

The weathered black slate in the cliff forming the roof of the rock-house looks exactly like a stained yellow sandstone, and would have been left as such but for the expectation of finding black slate there.

On the right, ¼ mile up the left fork of Trace, Jasper Watts has a 12-yard entry, 10 feet above the creek, with this section:

Fire-clay Coal.

Sandstone ..	5 ft.
Coal..	21″
Black jack	3″
Flint clay	4″
Coal ..	10″
Sandstone ..	3″
Coal ..	7″

The lower parting is a black, bituminous clay sandstone, which, in an entry 10 yards below is replaced by 2 inches of impure coal. The upper half of the visible sandstone covering the coal is smooth and massive; the lower half of irregular formation with thin coal seams running through it at varying pitches.

On the right fork of Trace, on the right ¼ mile up it, is an 8-yard entry into the Fire-clay coal at altitude 1,080, and on the left, ½ mile up, 10 feet above stream at altitude 1,100, is an entry of Joseph Fort's, partly closed.

Sections of these two, the latter measured at outcrop, follows:

One-fourth Mile Up.

Shaly sandstone	15 ft.
Coal	20″
Black jack	2″
Flint clay	4″
Coal	10″
Black slate	1″
Coal	6″

One-Half Mile Up.

Sandy shale	2 ft.
Coal	18″
Black jack	2″
Flint clay	4″
Coal	9″
Bone coal	1″
Coal	6″

At ¾ mile up, the Fire-clay coal is below drainage A 20-inch coal under 5 feet of shale and that under sandstone is exposed on the right at altitude 1,165.

On the left, ¾ mile up, Valentine Mullins has a closed entry with 3½ feet of coal under 5 feet of sandstone. Though, at altitude 1,465, it appears to be at the right height above the Fire-clay coal for the Hazard bed but the prevalence of Flag coal openings of this thickness induces correlation with the Flag bed.

On the right, 1½ miles up the right fork, Riley Mullins has a 10-yard entry into the Flag bed at altitude 1,525, in which is 40 inches of coal with an inch of shale parting 6 inches from the bottom. On it is 5 feet of massive sandstone.

At 1¾ miles up this fork divides again. A quarter mile up the left fork here, on the left, T. S. Evans has a 20-yard entry into 42 inches of Flag coal under sandstone, at altitude 1,505. An inch of hard black parting some 4 yards in, 7 inches from the bottom, seems not to be continuous, although corresponding in position with the parting in the preceding, Riley Mullins entry.

At the head of the right fork and two miles from the mouth of Trace, Mr. Fields has a 4-yard wet entry giving the following at its mouth:

Hindman Coal.

Shale	10 ft.
Coal	67"
Clay	2"
Coal	7"
Clay	1"
Coal	42"

Altitude, 1,660.

The bed here has little covering, but, westward the high hills toward the head of Lots creek offer a favorable field.

The following six sections represent openings into the Fire-clay coal on main Irishman creek and short branches between Trace fork and the forks at the school house, 2½ miles up.

On the right of a right branch, ⅛ mile above Trace fork and a like distance up the branch, ⅞ mile from Carr, Murray Combs has a 5-yard entry at altitude 1,175. On the left, one mile up the creek, Samuel Cook has a 10-yard entry at altitude 1,140.

Murray Combs.

Sandstone.	
Shale	3 ft.
Coal	24"
Black jack / Flint clay	6"
Coal	12"
Black slate	2"
Coal	6"

Samuel Combs.

Shale.	
Coal	24"
Black Jack	3"
Flint clay	3"
Coal	17"

Water in the Cook entry prevented satisfactory examination of the bottom coal, but it is apparently all good.

On the right of a right branch, 1¼ miles up the creek, ¼ mile up the branch, 25 feet above it, Jack Madden has

a 5-yard wet entry at altitude 1,175. On the right of the creek, 1⅝ miles up it, Jack Asher has a 15-yard entry at altitude 1,135.

Jack Madden.

Massive sandstone	15 ft.
Cannel slate	2"
Coal	20"
Black jack	3"
Flint clay	5"
Coal	13"
Bone coal	2"
Coal	4"
Clay.	

Jack Asher.

Sandstone	20 ft.
Shale	4 ft.
Cannel slate	2"
Coal	19"
Black jack / Flint clay	6"
Coal	11"
Slate	2"
Coal	4"

BIG BRANCH is on the right, 1⅞ miles up. On its left, ½ mile up is a 6-yard entry at altitude 1,180.

MILL BRANCH is on the right, 2⅛ miles up. P. Johnson has an entry at altitude 1,170.

Big Branch.

Sandstone	10 ft.
Cannel slate	1"
Coal	22"
Black jack	0 to 3"
Flint clay	4"
Coal	12"
Bone coal	2"
Coal	3"

Mill Branch.

Shaly substance	10 ft.
Coal	26"
Black jack	1 to 5"
Coal	12"
Bone coal	?

In Big branch the Whitesburg bed is exposed under black slate, its thickness not known, its altitude 1,140.

On the right, 100 yards above Mill branch, John Madden has the Whitesburg bed opened at altitude 1,120 with 34 inches of coal under 3 feet of black slate and 10 feet of shaly sandstone. The upper 10 inches of coal has a considerable deposit of marcasite on its face. This is the only place in the field covered by this report where sulphur has been observed to any marked degree, and there are very few places where it is visible at all, either as marcasite or pyrite. Across the creek from this opening the same coal is 38 inches thick.

LEFT FORK.—At School No. 12, 2½ miles up: Altitude of mouth, 1,064.

On the right of a left branch of this fork, ⅛ mile up each, Charles Madden has a 4-yard wet entry into the Fire-clay coal at altitude 1,225. On the right, ½ mile up the fork, the Fire-clay coal is opened at altitude 1,200 and all strata are exposed up to and beyond the rider. Sections from these two places follow:

Left Branch.

Shale	5 ft.
Coal	24″
Black jack	3″
Flint clay	4″
Coal.	

On Right.

Shaly sandstone	10 ft.
Shale	5 ft.
Coal	28″
Shale and coal	10″
Coal	4″
Shale	6 ft
Coal	5″
Shale	2 ft.
Coal	5″
Shaly sandstone	8 ft.
Coal	26″
Black jack	3″
Flint clay	3″
Coal	11″
Hard bottom.	

At ¾ mile up the fork the Fire-clay coal goes below drainage: Altitude 1,210.

On the left, one mile up, Bud Madden has a prospect which gives the following:

Flag Coal.

Sandstone	2 ft.
Shale	8 ft.
Block coal	41"
Shale	2"
Coal	1"
Clay.	

Altitude, 1,530.

On the left, in front of Samuel Pigman's house, 1¾ miles up, 10 feet above the fork, an incomplete prospect gives 20 inches of coal under 5 feet of shale, at altitude 1,310.

On the right of the road, 2 miles up the fork, 4½ miles from Carr, Samuel Pigman has a closed entry into the Flag coal, probably over 4 feet thick, at altitude 1,550. A thick sandstone shows 10 feet above the bed and a 70-foot sandstone crowns the peak above it, which reaches an altitude of 1,900.

RIGHT FORK.—At 2½ miles from Carr.

Alum Cave branch is on the right of this fork, ¼ mile up it, and the altitude at its mouth is 1,160.

On the left, ½ mile up the branch is a 2-yard entry into 25 inches of coal with 3 inches of black slate covering it, on which is 5 feet of massive sandstone. The (exact) altitude of the bed is 1,205. It lies so near the level of the Fire-clay coal that the flint clay parting is to be expected in its floor.

On the right of the head of the branch, 1¼ miles up, John Madden has a 10-yard entry into the Flag bed at altitude 1,615. This gives 50 inches of clean coal with 1½ feet of shale between it and the sandstone above. The broad bench of the Francis coal, 60 feet above the Flag bed is prominent here.

On the right of the fork at the mouth of Alum Cave branch, 25 feet above it, at altitude 1,185 is a thin coal with fire-clay floor on 15 feet of shaly sandstone, and

covering of 15 feet of shale under sandstone. This appears to be of the Whitesburg bed, but without the black slate roof the correlation is doubtful.

On the right of the fork, ¾ mile up it, 3¼ miles from Carr, Mrs. Madden has two entries with section as follows:

Fire-clay Coal.

Sandstone	5 ft.
Shale	1 ft.
Coal	28"
Parting	7"
Hard block coal	6"
Block coal	5"
Fire clay	1 ft.
Shaly sandstone to creek	2 ft.

Altitude, 1,200.

The parting is of uniform thickness but variable in contents, the flint clay being from 1 inch to 4 inches thick and the flint fire-clay from 6 inches to 3 inches. Bone coal was found 2 inches thick in the 28 inches of coal, 5 inches from the bottom, but it is not constant.

In the list of Flag coal openings on this creek must be added the Mullins 60 inches coal at the head of this fork given in Bulletin No. 11, page 103.

THE COALS OF THE UPPER CARR FORK AND BIG BRANCH AND BULL CREEK REGION OF NORTH FORK OF KENTUCKY RIVER.

BY

JAMES M. HODGE.

This report is in addition to the previous one in this volume giving details of the coals of Carr fork up to and including Irishman creek, and comprises all data collected early in the year 1913 regarding the coals of Carr fork and its branches above Irishman creek, as well as those of tributaries on the northwest side of the North fork of Kentucky river, above Carr fork up to and including Bull creek.

In the last decade there has been an almost complete abandonment of wood fires by the inhabitants of Eastern Kentucky, coal being now in general use. This has led to the making of many openings, which during the winter are accessible, but in summer are often banked up with water falls of earth from the mouths of entries. Exposures enough remain, however, to give, in most localities a fairly accurate knowledge of the bed best adapted to local use, and occasional other prospecting helps to carry correlations through the region and give a general knowledge of nearly all the beds of the field.

Strata above drainage in this region include about 600 feet above the Fire-clay coal bed and 250 feet below it, but only in the river hill between Big branch and Bull creek can they all be found in one locality.

The principal bed of the region is unquestionably the Fire-clay coal. On it main dependence must be placed, while other beds are regarded as the source of additional supply, wherever they provide workable areas. This coal is of workable thickness in all but a few small parts of the region, as the detailed description comprising the bulk of this report shows; its principal coal seam (the upper bench) is of exceptionally good and uniform qual-

ity and its under seam has much good coal in it, including cannel at one point; its roof is usually a good sandstone even when it appears as shale on the outcrop—so good that the farmer miner will abandon a thicker coal in preference to it, and the bed is at moderately convenient height throughout the region, covering probably over three-quarters of it.

The Whitesburg bed seems to vary in its distance from the Fire-clay coal, from about 25 feet below it to as much as 100 feet, the latter on Collins branch where it is in part cannel coal. On Little Carr it is also partly cannel, but at neither place does it add to the value of the bed. With varied section including more or less of partings its workable area is probably limited to Carr fork from Breeding to Branham creeks, with possibly half of the branches included.

The Amburgy bed, uniformly 200 feet below the Fire-clay coal, is probably workable along Carr fork from Irishman creek (where it is slightly below drainage) to Deer fork, but elsewhere it is too thin or too much cut up by partings, and such condition is to be expected of it away from the immediate vicinity of Carr fork, where it is below drainage and as yet undeveloped.

Attention is here called to a coal bed about 20 feet under the Amburgy, very thin so far as known, and unimportant, but remarkable for its persistency.

Above the Fire-clay coal, its rider and the Flag coal are the only beds known of workable thickness and sufficient area. The rider has been found especially attractive on Smith branch, 17½ miles up Carr, and on Deer fork, but it is generally either much hurt by partings or thin.

The Flag coal continues in this field, so far as known, its condition as shown lower down Carr and on Lost creek, a good thick coal, generally without partings, under a strong sandstone roof. Wherever its area permits mining it will be most attractive, but there is probably no such area of it above Betty Troublesome.

The Hindman bed is lacking in area all through this region excepting on Betty Troublesome. It retain its height of about 530 feet above the Fire-clay coal.

The sandstone directly under the Haddix coal bed seems to be particularly favorable for obtaining good

flag-stones for local use, several quarries having been noted in that position.

For the new railway up the river good building stones were always obtained at convenient places in this region from near the level of the Amburgy coal bed.

The 20 to 30 feet of cliff-forming sandstone under the Hazard coal retains that characteristic in this region, and in that part of it between Carr fork and Bull creek its excessive hardness has been the chief cause of the unusually broad areas on or near the tops of the ridges, giving farms and habitations on their comparatively light slopes, to which is given the name of "flat-woods."

The northwest dip of strata continues, with minor variations, up Carr fork to its head, but along the river it is interrupted by a nearly level, apparently undulating, rise and fall from Carr fork to Bull creek, and a rise up Bull creek, where normally the rocks should be level, to meet the rise up Carr and its branches to opposite the heads of Bull creek.

In the following detailed description is included all observed data of strata noted with a view to obtaining not only the fullest knowledge possible under present conditions of development of all workable beds, but also of such others as may become workable in the future, or may assist in correlation.

Measurements given in inches are exact unless otherwise stated, given in feet are approximate only. Distances in yards are by estimation and in miles as obtained from maps or by report or estimation. In ascertaining distances up Carr fork from its mouth, there may be in the total a considerable error, but for approximate distances from point to point not far apart they may be relied upon.

Altitudes of mouths of streams are very nearly correct as given, recently taken levels having been carried over most of the region. Altitudes of coal openings were determined by barometer, but, with opportunities for reference to those levels usually at hand, the altitudes are far more reliable than were those of former years.

Those entries are designated wet which had water in them (usually six inches to a foot deep) which prevented access to the face of the coal. At them the beds were measured in outcrop, so fas as they admitted.

CARR FORK.

The Spencer Combs 15-yard wet entry on the left, 1/8 mile above Irishman creek, at altitude 1,140 (taken from Bulletin No. 11), has the following slightly corrected section:

Fire-clay Coal.

Sandstone	5 ft.
Coal	26"
Flint clay	5"
Coal	8"
Clay	1"
Coal	8"

LITTLE BRANCH.—On the right of Carr fork, 11¼ miles up Carr. Altitude of mouth, 985.

The only opening on this branch is the new Goodloe Bros. 12-yard entry at altitude 1,190, given in Bulletin No. 11, page 103. A later measurement gives this as follows:

Fire-clay Coal.

Shale.	
Coal	34"
Black jack	4"
Flint clay	5"
Coal	18"

The bottom one or two inches of coal sticks to the black jack in mining.

SMITH BRANCH.—On the right, 11⅜ miles up Carr. Altitude of mouth, 985.

On the left of the first left fork, ¾ mile up it and 1½ miles from Carr, Riley (or Hillard) Smith has two long entries in a rock-house at altitude 1,215, previously reported but with new measurements given here. On the right, ¼ mile up the second left fork and 1¾ miles from Carr, Riley Combs has a 7-yard entry at altitude 1,210, with section as follows also, both entries being in Fire-clay coal:

Smith Entry.

Sandstone	25 ft.
Shale	1 ft.
Coal	33"
Black jack	4"
Flint clay	3"
Coal	17"

Combs Entry.

Sandstone	10 ft.
Coal	34"
Black jack	4"
Flint clay	4"
Coal	7"
Bone coal	1"
Coal	2"
Bone coal	1"
Coal	7"

No bone coal was detected in the Smith entry but coal sticks to the black jack as on Little branch, the one merging into the other by almost imperceptible changes. The shale changes to sandstone under cover.

On the left of Carr fork, 12 miles up it, Shade Smith has a prospect on the right of the easterly small branch by his house giving the following section:

Fire-clay Coal.

Sandstone.	
Shale	5 ft.
Coal	28"
Black jack	4"
Flint clay	4"
Coal	10"
Bone coal	4"
Coal	5"
Fire clay	2 ft.
Sandstone	10 ft.

This opening is 200 feet above Carr and at or near this point a coal bed rises to creek level and continues with it for 1½ miles or more up stream, and is the source from which the greater part of the coal supply of the vicinity is drawn. It is reported generally about 4 feet thick, 46 to 50 inches in one instance, and this is believed to be nearly correct. It is said to be without parting,

but, in view of the partings found in the bed where it rises above the creek this seems somewhat doubtful. Partings under water may escape discovery. Over this bed is about 50 feet of shale.

In previous reports this bed has been called the Elkhorn bed, and came to be regarded as the equivalent of the Elkhorn coal now mined at McRoberts and Jenkins, whereas it is probable that it was intended to be correlated with a higher coal—the Upper Elkhorn. Be that as it may, confusion is liable to result from the use of one name for two beds and this one is now given the entirely new name of "Amburgy" coal bed. Where in Bulletin No. 11, the Elkhorn coal is referred to 200 feet below the Fire-clay coal this name Amburgy should be substituted, but this does not include the thick coal on Boone fork and elsewhere about the head of the river, which, like the Rockhouse coal, is 400 feet below the Fire-clay and is the true Elkhorn bed.

DEFEATED BRANCH.—On the right, 12¾ miles up Carr. Altitude of mouth, 1,000.

On the left, ¼ mile up a right branch, ¼ mile up Defeated branch, C. C. Hilton has a 20-yard entry into the Fire-clay coal at altitude 1,215. Wet at the face, the measurement following was taken about half way in. On the left of a left drain, 1¾ miles up Mr. Hilton has another entry, barely under cover, into the same bed at altitude 1,310. Its section also follows:

C. C. Hilton No. 1.

Sandstone	3 ft.
Coal	20"
Black jack	3"
Flint clay	4"
Coal	13"
Bone	3"
Coal	4"

C. C. Hilton No. 2.

Massive sandstone.	
Coal	37"
Black jack	3 to 4"
Flint clay	4 to 3"
Coal	10"
Bone Coal	10"

Two miles up the creek to the forks and up the right fork, ¼ mile to a right branch and on the right, ¼ mile up this and 20 feet above it, C. C. Hilton's four-yard wet entry into the Fire-clay coal at altitude 1,300 with the section following. A half mile up the left fork two miles up Defeated, ⅛ mile up the left branch there, on the right of the trail to Breeding creek, Alamanda Blair has a 20-yard entry into the same bed at altitude 1,360 with section also following:

Hilton.

Massive sandstone.	
Shale	3 ft.
Coal	4"
Shale	7"
Coal	40"
Black jack	3"
Flint clay	4"
Coal	6"
Bone coal	2"
Coal	4"

Blair.

Sandstone.	
Coal	37"
Black jack	3"
Flint clay	5"
Coal	18"

The bottom coal of the Blair entry may contain bone coal, it was not in condition for close inspection.

BREEDING CREEK.—(Formerly Little Carr.) On the right, 12¾ miles up Carr. Altitude of mouth, 1,000.

On the right of a left branch, ¾ mile up Breeding creek, ¼ mile up the branch, James Bass has a wet entry into the Fire-clay coal at altitude 1,225, with the following section:

Fire-clay Coal.

Shale	5 ft.
Coal	32"
Black jack	2"
Flint clay	4"
Coal	10"
Parting	1"
Coal	3"

On the left, 1¼ miles up is the following exposures:

Shale	10 ft.
Block coal	4″
Splint coal	5″
Black slate	4″
Shale to creek	6 ft.

At altitude 1045.

Doubtless this is a rider to the Amburgy coal bed, which then is probably not more than 10 feet below water level.

SUGAR BRANCH.—On the right, 1⅝ miles up Breeding creek.

On the left of a right drain, ¼ mile up the branch, is John Buck's 5-yard entry into the Fire-clay coal, given in Bulletin No. 11. Following is a corrected section:

Fire-clay Coal.

Shaly sandstone.	
Coal	32″
Fire clay	5″
Coal	12″

On the left at the branch, ¾ mile up it, Jesse Amburgy has a 2-yard entry into the same bed at altitude 1,305, with like section but with 2 inches of black jack added and 2 inches more coal above that.

MALLET FORK.—On the right, 1¾ miles up Breeding creek.

On the right, ⅛ mile up the fork, at water level, the rider to the Amburgy coal shows 8 inches thick under 20 feet of shale at altitude 1,120. On the hill oposite this John Hale has a 25-yard entry into the Fire-clay coal at altitude 1,315. On the right of a left branch of Mallet fork, ¼ mile up it and the same distance up the branch, William Hale has an opening into the same bed at altitude 1,350. Sections of these two openings follow:

John Hale.

Sandstone	20 ft.
Coal	27″
Bony coal	4″
Flint clay	4″
Coal	12″

William Hale.

Sandstone	5 ft.
Coal	32″
Bone coal	3″
Flint clay	5′
Coal	12″

On the left of a left branch, ½ mile up Mallet fork, ⅛ mile up the branch, Noah Gent has a 20-yard entry at altitude 1,340. On the left at the head of Mallet fork, one mile up it, Daniel Adams has a 20-yard entry at altitude 1,305, which if nearly correct, as it probably is, gives a reverse dip at the head of this fork. Sections from these two Fire-clay coal entries follow, the Gent section varying somewhat from that previously reported:

Gent.

Sandstone	8 ft.
Coal	30″
Bony coal	1″
Flint clay	4″
Coal	12″

Adams.

Sandstone	10 ft.
Coal	30″
Black jack	4″
Flint clay	4″
Coal	9″

LEFT FORK.—Two and one-quarter miles up Breeding.

On the left branch, ¾ mile up this fork, on the left, ⅛ mile up it, Harlan Williams has a 4-yard entry at altitude 1,380; and on the right of a drain on the left, ⅞ mile up the fork, Fraser Adams has one of 12 yards. Both are in the Fire-clay coal and they gave the following sections:

Williams.

Sandstone	4 ft.
Coal	29″
Black jack	2″
Flint clay	4″
Coal	9″

Adams.

Shaly sandstone	10 ft.
Shale	2 ft.
Cannel slate	2″
Clay	1″
Coal	25″
Black jack	1″
Flint clay	5″
Coal	10″

In a left drain one mile up, an old opening gives the bed's altitude at 1,415 and at 1⅛ mile up, where it goes below drainage, it is 1,425. This rapid rise of strata is made evident also in their exposure along the stream.

On the left of a left branch 2⅜ miles up the creek, ¼ mile up the branch, George Breeding has a 12-yard entry at altitude 1,350; and on a right branch, 2¾ miles up Breeding creek, on the right, ⅛ and ¼ miles up the branch, William Breeding has 3-yard and 10-yard entries at altitudes 1,390 and 1,400. These three Fire-clay coal entries give the following:

	1350.	1390.	1400.
Sandstone	10 ft.	5 ft.	
Shale	4 ft.	none	7 ft.
Coal	27″	25″	28″
Flint clay	5″	6″	6″
Coal	7″	11″	12″

The flint fire-clay of the first of these is black, of the second both brown and black and of the third brown only.

On a left branch 3 miles up Breeding creek, on the right, ¼ mile up it, beside the road to Wolf-Pen branch, William Johnson has a long entry at altitude 1,390, and on the right, 3½ miles up, beside the road to Rockhouse creek, ⅛ mile from the gap, James Breeding has one at altitude 1,395. Sections of these two Fire-clay coal openings follow:

Johnson.

Thin bedded sand-sandstone	5 ft.
Black slate	4″
Clay	11″
Coal	27″
Flint clay	6″
Coal	12;

Breeding.

Sandstone	5 ft.
Shale	6 ft.
Cannel coal	1"
Coal	25"
Flint clay	6"
Coal	12"

The latter entry is but 85 feet below the gap to Rockhouse creek, but the hills are high enough to give the bed large area.

In a left branch, 13½ miles up Carr fork, ⅛ mile up the branch, Samuel Francis has a pit from which, apparently 30 inches of good block coal is taken, but the lower half being hidden in water, was not seen in place. With an altitude of 1,115, it is probably of the Whitesburg bed, though, being about 70 feet under the Fire-clay coal, the interval is large for that correlation. The rock covering was not seen and cannel coal and slate may cover the bed as they do on Little Carr not far distant.

The Fire-clay coal is opened on the same branch, on the right, ¼ mile up it, where a 6-yard entry gives the following:

Fire-clay Coal.

Sandstone	8 ft.
Shale	1 ft.
Coal	30"
Black jack	3"
Flint clay	4"
Coal	10"
Shale	5"
Coal	4"

Altitude, 1190.

On the right, 14 miles up Car, Henry Blair has a 2-yard entry, 3 feet above the creek, into the Amburgy coal, which here makes its first appearance above water level. The following section was obtained here:

Amburgy Coal.

Shale	5 ft.
Coal	3″
Shale	10 ft.
Coal	2″
Shale	6″
Coal	1″
Shale	3″
Coal	38″
Black slate	2″
Fire clay	2 ft.
Sandstone in creek.	

Altitude, 1010.

The bed is at creek level 100 yards farther up. At 14⅛ miles up, a prospect into this bed gives 37 inches of coal with an inch of black slate 3 inches from the top. At the mill, 14¼ miles up, 30 to 40 feet of shale are exposed over the coal with massive sandstone above the shale. On the left of the creek and road, 15⅛ miles up Carr, the bed gives the following section:

Amburgy Coal.

Shale	5 ft.
Coal	1″
Shale	10″
Coal	3″
Slate	2″
Coal	34″
Shale	1″
Coal	3″

Altitude, 1030.

On the right, 15¼ miles up Carr (below Little Carr) this bed has in its main seam only 27 inches of coal under 3 feet of shale and then 5 feet of sandstone. This massive sandstone can be seen for a mile down the creek, about 10 feet above the coal, but farther down its place is occupied by shale. Besides this entry a rider appears to start from the coal. It is a continuous feature farther up the creek.

A quarter mile to the left, 15¼ miles up Carr fork opposite the mouth of Little Carr, Andrew Combs has an abandoned prospect into cannel coal at altitude 1,155, from which blocks a foot thick were taken. The place

was abandoned because unsuitable for opening rather than because of thin coal. An entry into the bed has been made a half mile up Little Carr.

LITTLE CARR.—(Formerly Amburgy branch.) On the right, 15¼ miles up Carr fork. Altitude of mouth, 1,020.

On the right, ¼ mile up, H. H. Amburgy has a 12-yard wet entry, 15 feet above the creek from which the following was obtained:

Amburgy Coal.

Shale	10 ft.
Coal	15″
Shale	1 ft.
Black slate	1″
Coal	2″
Shale	2″
Coal	36″

Altitude, 1045.

On the right of a left branch, ½ mile up Little Carr, ⅛ mile up the branch, Floyd Taylor has a 10-yard entry into the Whitesburg bed about 50 feet under the Fire-clay coal. Its section is:

Whitesburg Coal.

Shale	10 ft.
Cannel slate	12″
Cannel coal	6″
Block coal	6″
Slate and pyrite	1′
Block coal	37″

Altitude, 1200.

The block coal is particularly bright and rich-looking; the 6 inches of cannel looks very good but its weight betrays a large amount of ash. There is no definite plane of change from the cannel to the coal below or to the slate above it, one merging into the other.

On the right, 1¼ mlies up Little Carr, a lone exposure of cliff with entries 5 feet above the creek, gives:

Amburgy Coal.

Shale	15 ft.
Coal	12″
Shale with calcareous concretions	2½ to 4 ft.
Coal	2″
Shale	8″
Coal	30″
Shale	1″
Coal	4″
Shale and coal	5 ft.
Thin-bedded sandstone in creek.	

Altitude, 1070.

WOLF-PEN BRANCH.—On the right, 1½ miles up Little Carr. Altitude of mouth, 1,075.

On the right, ⅛ mile up the branch and 3 feet above it is the following in outcrop:

Amburgy Coal.

Shaly sandstone	5 ft.
Coal	1″
Shale	1″
Coal	2″
Shale	12″
Coal	28″
Bony coal	2″
Shale	1″
Coal	9″

Altitude, 1090.

Coal in the branch, ¼ mile up, altitude 1,120, is probably of the rider, not seen in the preceding section.

On the right, ¼ mile up Leck branch, which is on the right, 1¼ miles up Wolf-Pen, B. F. Hammond has an opening into the Fire-clay coal at altitude 1,380. On the right of Wolf-Pen, 1½ miles up, Joseph Raleigh has a 10-yard entry, into the same bed at altitude 1,400, 140 feet above the creek. The sections of the Fire-clay coal at these two places are:

Hammond.

Sandstone	5 ft.
Coal	26″
Flint clay	4 to 6″
Coal	12″

Raleigh.

Shale	6 ft.
Coal	29″
Flint clay	6″
Coal	12″

On the right, 1¾ miles up Wolf-Pen, Tandy Amburgy has a 25-yard entry with the following section, measured at the face:

Fireclay Coal.

Shale	8 ft.
Coal	32″
Black jack	6″
Cannel coal	24″

Altitude, 1395.

The impression prevails that this is the same bed that is opened into cannel coal near the mouth of Little Carr (the Whitesburg bed), and its altitude, as obtained, is indicative of that bed, but the cannel in this entry is at the bottom of the bed, whereas in the other it is at the top, and the usual black slate covering of the Whitesburg bed in wanting. Moreover the parting, though not the almost invariable accompaniment of the Fire-clay coal, the brown flint fire-clay, is just such a compound of fire-clay and black slate as is found at nearly every opening of the Fire-clay coal bed on Carr fork waters, and never but once anywhere, by the writer, in the Whitesburg bed. The conclusion then is, either that the barometric altitude is incorrect, or that a reversal of the upstream rise of strata occurs on the head of Wolf-Pen. No reversal has been found elsewhere on Little Carr.

The cannel of this opening is fine-looking and light in weight. Analyses of bituminous coal and cannel both are taken from Bulletin No. 11:

Fire-clay Coal.	Bituminous.	Cannel.
Moisture	5.46	0.26
Volatile combustible matter	31.68	47.94
Fixed carbon	57.46	44.86
Ash	5.40	6.94
Sulphur	0.488	0.751
Specific gravity	1.385	....

The cannel is said to be explosive in burning.

Across the divide at the head of Wolf-Pen, on the head of Stamper branch of Rockhouse creek, about a mile east of the preceding, Cordelia Hammon has a closed entry in which is over 5 feet of block and splint coal, (probably including 2 inches of slate found in the dump); its altitude 1,940.

This is probably of the Hindman bed, quite possibly the 77 inches coal with 4 inches parting given in Bulletin No. 11, page 108, as no other such opening was found in the vicinity. It indicates nearly level strata from the cannel opening on Wolf-Pen. Being 100 feet above the Wolf-Pen gap, with little area, its value lies only in local use.

On the right, two miles up little Carr is a 12-yard entry, 3 feet above the creek, where the following section was obtained, the lower seams measured half way in:

Amburgy Coal.

Sandstone	5 ft.
Shale	20 ft.
Coal	5″
Shale	12 ft.
Coal	3″
Shale	20″
Coal	3″
Shale	1″
Coal	30″

Altitude, 1115.

LITTLE DOUBLE BRANCH.—On the right, 2⅜ miles up Little Carr. Altitude of mouth, 1,125.

The three sections following give the only openings now on this branch. The first is on the right of a left drain, ⅛ mile up the branch; Jesse Pigman's 8-yard wet entry; the second is on the right, ⅜ mile up, Jack Hammond's wet entry; and the third is on the left, ¾ mile up, William Ward's entry. They are all in the Fire-clay coal at altitudes 1,380, 1,390 and 1,400, respectively:

	Pigman.	Hammond.	Ward.
Sandstone	10 ft.	5 ft.	
Shale	3 ft.	0	10 ft.
Coal	30″	32″	32″
Black jack	3″	3″	6″
Flint clay	4″	4″	0
Bone coal	0	0	1″
Coal	11″	13″	9″

It is to be noted that in the third section, nearest to the cannel coal on Wolf-Pen, the flint fire-clay is absent, as in the cannel opening.

BIG DOUBLE BRANCH.—On the right, 2½ miles up Little Carr. Altitude of mouth, 1,130.

On the left at the mouth of the branch a prospect gives the following:

Amburgy Coal.

Shale.	
Coal.	
Shale	3 ft.
Block coal	26″
Slate	2″
Coal	2″

Altitude, 1150.

The three sections given next are, first, from ¼ mile up left branch, ⅜ mile up Big Double branch, Andrew Case's 7-yard entry; second, from the left of a left drain, ⅛ mile up it, ½ mile up Big Double, Jefferson Amburgy's 6-yard entry; third, from on the right, across the hollow from the second, 80 yards southeast of it, W. F. Amburgy's 25-yard entry. These are all in the Fire-clay coal, at altitudes 1,385, 1,350, 1,370, respectively:

	Case.	J. Amburgy.	W. F. Amburgy.
Sandstone	1 ft.	1 ft.	
Shale	8 ft.	0	2 ft.
Coal	34″	32″	37″
Flint clay	6″	6″	5′
Coal	12″	9″	8″

Jenny Lewis branch is on the left, ¾ mile up Big Double. On the right of the branch ¼ mile up it, Jasper Amburgy has a 25-yard entry, its section following:

On the left of the right fork of Big Double at its head, 1½ miles from its mouth, Lindsey Amburgy has a 15-yard entry with the section following. Both of these are in the Fire-clay coal, at altitudes 1,375 and 1,410, respectively:

Jasper Amburgy.

Shale	10 ft.
Coal	34″
Flint clay	2″
Coal	5″

Lindsey Amburgy.

Shaly sandstone	6 ft.
Coal	34″
Bony coal	2″
Flint clay	6″
Coal	6″

On the right of Little Carr, 2⅝ miles up it, ⅛ mile above Big Double, the Amburgy bed shows, at altitude 1,145, 10 feet above the creek, 30 inches of coal with a knife-edge of shale 3 inches from the top.

STILLHOUSE BRANCH.—On the left 2¾ miles up Little Carr.

The Whitesburg coal shows its covering in a thick bed of black slate up this branch the coal under it, reported two feet thick, being at altitude 1,285.

On the right of the branch, ½ mile up it, George Gibson has an 8-yard wet entry, the main coal seam reported about 28 inches thick with parting and lower coal each about 4 inches. Two feet of shale and then 5 feet of sandstone overlie it. Its altitude is 1,350.

The top seam of the Amburgy coal goes under the creek at the mill, 3 miles up Little Carr.

LEFT FORK.—On the left, 3⅜ miles up Little Carr.

There are two entries into the Whitesburg bed, each ¼ mile up this fork and at altitude 1,355, one on the left, the J. W. Collins 8-yard entry, having 38 inches of coal under 10 inches of black slate, the other on the right, the Nancy Gent 5-yard wet entry, having 34 inches of coal under 3 feet of black slate.

The Fire-clay coal is opened on the right, ¾ mile up the fork in Tandy Martin's 5-yard wet entry, at altitude 1,430. More than 2½ feet of coal was visible, under 3 inches of black slate and 20 feet of shale, in the middle of which is 1½ feet of sandstone. This thin sandstone shows in shale or earth over the Fire-clay coal at several places in this vicinity.

RIGHT (MAIN ROAD) FORK.—On the right, 3⅜ miles up Little Carr.

On the right of the fork, ¼ mile up it, Robert Collins has a 15-yard wet entry at altitude 1,450, showing 38 inches of the main seam of the Fire-clay coal under 10 feet of shale. Nine inches more coal is reported under the parting below. In the point of the hill on the way up to this entry the black slate of the Whitesburg bed crops out at altitude, 1,385.

On the left, ¾ mile up this fork, Charles Logan has a 15-yard entry into the Fire-clay coal at altitude 1,450, having 34 inches of coal under 2 inches of black slate, then 6 feet of shaly sandstone and then 3 feet of massive sandstone. The dump gave black flint fire-clay about 6 inches thick.

The Amburgy coal bed continues up Carr Fork slightly above the stream. A section of the bed as exposed beside the road, on the left, ⅛ mile above the mouth of Little Carr, is given, with analyses, in Bulletin No. 11, pages 105 and 106. Its altitude is exactly 1,030.

BETTY TROUBLESOME.—On the left, 15¾ miles up Carr Fork. Altitude of mouth, 1,030.

DICE'S (OR STILLHOUSE) BRANCH.—On the left, ⅛ mile up Beatty's Troublesome.

On the right, ¾ mile up this branch, W. F. Bentley has a 6-yard entry with the following section:

Fire-clay Coal.

Shale	5 ft.
Coal	28"
Flint clay	3"
Coal	7"
Bone coal	2"
Coal	9"
Black slate	3"

Altitude, 1195.

DEADMAN'S BRANCH.—On the right, ¼ mile up Betty Troublesome.

On the left, ¾ mile up the branch, 10 feet above it, a foot of the coal of the Whitesburg bed is exposed, under 3 feet of black slate, but no attempt to open it has been made. Its altitude is 1,180.

Thirty feet higher about the same thickness of the Fire-clay coal outcrops, altitude 1,210.

On the left, ¼ mile up a left branch, ⅞ mile up Betty Troublesome, Jefferson Hall has a wet entry from which the following was obtained:

Shale	3 ft.
Coal	26"
Black jack	4"
Flint clay	3"
Coal	10"
Black slate	3"

The bottom coal and slate measure 13 inches; the proportion given of each may be slightly erroneous.

TURKEY-PEN BRANCH.—On the left, 1 mile up Betty Troublesome. Altitude of mouth, 1,088.

On the right, ¼ mile up a left branch, ¼ mile up Turkey-Pen, Noah Reynolds has a wet entry but with an exceptionally good opportunity to measure the bed at the outcrop.

On the left ¾ mile up Turkey-Pen, 20 feet above it, Reuben Amburgy (or Nicholas Combs) has a 10-yard entry. Both of these entries are in the Fire-clay coal, at altitudes 1,180 and 1,220, respectfully, and sections of them follows:

Reynolds.

Shale	2 ft.
Coal	6"
Shale	6 ft.
Coal	26"
Black jack	6"
Flint clay	3"
Coal	1"
Bone coal	1"
Coal	11"

Amburgy's.

Sandstone.	
Shale	3 ft.
Coal	28″
Black jack	4″
Flint clay	2″
Coal	14″

In the central peak at the head of Turkey-Pen, 1¼ miles from its mouth, Marion Tolliver has an entry into the Flag coal, at altitude 1,625, giving 54 inches of fine bright block coal, the lower half hard, under 1½ feet of shale and 4 feet of sandstone. The area of the bed here is very small.

An attempt was made in former prospecting to get a full section of the coals on the right, 1¼ miles up Betty Troublesome, at Leander Parks'. Following are the results obtained from recent examination there: The openings were made so nearly over one another that dip may be disregarded.

	Altitude.
High peak	1865
Prospect, 2 feet coal seen, reported 88 inches	1675
Prospect, 2½ feet coal seen, reported 62 inches	1630
Prospect, covered coal, probably thin	1325
Prospect, Fire-clay coal rider	1270
8-yard entry—Fire-clay coal (in full below)	1240
Prospect—Whitesburg coal, 1½ feet	1210
Creek	1120

The Whitesburg bed is recognized by its 4 feet of black slate covering, over which is shaly sandstone.

The Fire-clay coal bed has 28 inches of coal in its main seam, and bottom coal of about 13 inches, with black jack and flint fire-clay parting of only 5 inches. Three feet of shale is exposed over the entry. The rider appears to be thin.

The two high beds of the section are believed to be of the Flag and Hindman beds with a possible error in altitude of the latter to account in part for the proximity of the two. If such is the case the interval from the Fire-clay coal to the Flag, 390 feet, corresponds nearly with results obtained heretofore.

The higher coal still has covering enough over it to admit of mining a fairly good area in this ridge, and no where else is so large an area of this coal so near to a large stream.

On the right of a right branch, 1½ miles up Betty Troublesome, ⅛ mile up the branch, Silas Martin has an 8-yard entry into the Fire-clay coal at altitude 1,240, and a 5-yard wet entry into the Whitesburg bed 40 feet lower. The sections of these follows:

Fire-clay Coal.

Sandstone	2 ft.
Shale	2 ft.
Coal	30″
Black jack	5″
Flint clay	2″
Coal	12″

Whitesburg Coal.

Shale	5 ft.
Coal	1″
Shale	2″
Coal	4″
Shale	2″
Coal	22″
Shale	1″
Coal	5″

The total thickness of the bed measures 41 inches, leaving four inches at the bottom which could not be determined in the deep water.

On the left of a right branch, 1¾ miles up Betty Troublesome, ⅛ mile up the branch, Thomas Hall has 10-yard and 4-yard entries into the Fire-clay and Whitesburg coals, at altitudes 1,260 and 1,230, respectively, with the sections following:

Fire-clay Coal.

Sandstone	5 ft.
Sandy shale	6 ft.
Coal	30″
Black jack and Flint clay	6″
Coal	10″

Whitesburg Coal.

Sandstone	15 ft.
Shale	1 ft.
Coal	1″
Shale	1 to 6″
Coal	6″
Shale	1″
Coal	24″
Shale	6″
Coal	6″

Nicholas Combs has a closed entry into the Whitesburg bed, 2¼ miles up the creek, at altitude 1,220. The Fire-clay coal shows above it at 1,250.

On the left, 2½ miles up, is a 4-yard wet entry into the Fire-clay coal at altitude 1,245, having in its main seam 29 inches of coal and about 9 inches coal under a parting of 8 inches black jack and flint clay. Eight feet of shale is exposed above it.

In the peak at the head of the creek, three miles from its mouth, Jasper Amburgy has a 1-yard entry with the following section:

Flag Coal.

Shale	10 ft.
Coal	46″
Black slate	5″
Coal	8″

Altitude, 1650.

The broad top of the ridge about 60 feet lower is due to the cliff sandstone under the Hazard coal bed.

On the left of the road and of Carr Fork, 16½ miles up and 20 feet above it, at altitude 1,055, the Amburgy bed has been driven under cover with top coals and partings substantially the same as follow in the section below and bottom seam of coal half covered. On the left by the road, 16¾ miles up Carr, this section was obtained:

Amburgy Coal.

Shale	10 ft.
Coal	9″
Shale	9″
Coal	2″
Shale	4″
Coal	34″

Shale to creek at 1040.

Altitude, 1055.

On the right, 16⅞ miles up Carr, J. E. Stamper has an opening into the same bed at altitude 1,080, showing about 2½ feet of coal at the bottom, 16 inches parting and 3 inches more of coal at the top, with 8 feet of shaly sandstone above it.

BUCKEYE BRANCH.—On the right, 17 miles up Carr. Altitude of mouth, 1,045.

On the right, ½ mile up the branch, J. E. Stamper has a 6-yard entry into the Fire-clay coal at altitude 1,280. The main seam is 30 inches thick and that only has been mined. The flint clay parting is 5 inches or more thick and 8 inches of coal is reported under it. Three feet of sandstone covers the bed.

On the left, 17⅛ miles up Carr, and on the right of the branch at Spider postoffice, John Banks has an 8-yard entry into the Amburgy coal at altitude 1,085, with 30 to 32 inches of coal under 12 inches of shale and with 2 inches of coal above that, and 20 feet of cliff sandstone overlying the bed. The change from the long series of exposures of apparently true clay shales, found below on the creek, to this massive sandstone is very striking. A quick return to shale follows.

SMITH BRANCH.—On the left, 17¼ miles up Carr. Altitude of mouth, 1,055.

On the right, ⅛ mile up this branch, an 8-yard entry gives the following:

Amburgy Coal.

Shale	3 ft.
Coal	3″
Shale	2 ft.
Coal	25″
Black slate	2″

Altitude, 1075.

A little coal may be under the slate, the bottom not having been seen.

On the left of a left branch, ½ mile up Smith branch, ⅛ mile up the left branch, Benton Stampers has a 2-yard entry into the Whitesburg coal at altitude 1,240, and a 12-yard entry into the Fire-clay coal rider, at altitude 1,290. Sections of these follow:

Whitesburg Coal.

Shale	4 ft.
Black slate	1½ ft.
Coal	22″

Fire-clay Coal Rider.

Shale.	
Coal	5″
Shale	¼ to 1″
Coal	27″
Slate	2″
Coal	4″

The slate in the rider is soft with contained coal and may be but little deleterious.

On the same left branch, ¼ mile up it, Mr. Stampers has a 6-yard wet entry into the Fire-clay coal at altitude 1,290, on the level of the preceding rider coal opening. This entry shows about 40 inches of coal, probably including 2 inches of black jack found in the dump. A foot of shale covers the coal, on which is sandstone in a slight roll which appears not to have effected the coal.

On the right of a left branch, 1½ miles up Smith branch, from ⅜ to ⅝ mile up the left branch, on Ezekiel Caudill's land, three beds show within 50 feet vertically. These are the Whitesburg, at altitude 1,205, with 24 inches of coal under 3 feet of black slate, in a slip which may not show all of the coal; the Fire-clay coal in a 15-yard entry at altitude 1,235, and the rider in a 4-yard entry at altitude 1,250. The last two give:

Fire-clay Coal.

Shale	4 ft.
Coal	28″
Flint clay	4″
Coal	11″

Fire-clay Coal Rider.

Shale	6 ft.
Coal	5″
Shale	1″
Coal	25″
Black slate	3″
Coal	2″
Black slate	1″
Coal	9″

The bottom seam of the Fire-clay coal is a good hard block with one inch splinty; the top is especially noted here as having no cleavage planes, general absent in Carr Fork openings.

On the right, 1⅞ miles up Smith branch, Robert Pigman has a 10-yard entry into the Fire-clay coal rider at altitude 1,260, and two miles up, a 6-yard entry into the same bed at 1,285. Sections of these two entries follows:

Altitude, 1260.

Shale	3 ft.
Coal	2″
Clay	½ to 2″
Coal	5″
Clay	1″
Coal	40″
Black slate	5″
Coal	5″

Altitude, 1285.

Sandstone.	
Shale	4 ft.
Cannel slate	2″
Shale	3″
Coal	30″
Black slate.	

On the right, 2⅛ miles up, the top of the Whitesburg bed, at altitude 1,250, shows a foot of coal under 4 feet of black slate.

The bed with the two entries is correlated as the rider, because of the similarity of these sections with those in this bed farther down the branch, and the Whitesburg bed because of its black slate roof. There seems to be no room for doubt in this, though it leaves little space for the intermediate Fire-clay coal.

By the road, on the left, 18¼ miles up Carr, at the mouth of an entry, at altitude 1,080, and again on the left, 18¾ miles up Carr, in J. W. Reedy's 8-yard entry, at altitude 1,095, the following sections were obtained:

Amburgy Coal.

	Altitude 1080.	Altitude, 1095.
Shale	6 ft.	10 ft.
Coal	2″	0
Shale	34″	0
Coal	28″	26″
Black slate	1″	2″
Clay	0	1″
Coal	3″	2″

These sections are particularly remarkable in showing a close resemblance to the fire-clay coal rider on Smith branch, a bed 200 feet higher in the series of strata.

This coal showing in the road opposite the mouth of Deer Fork lies about 30 feet below the Amburgy bed.

DEER FORK.—On the right, 19 miles up Carr. Altitude of mouth, 1,065.

On the right, ¼ mile up this fork is a coal about one foot thick, under shale, at water level and altitude 1,075.

On the left, ⅜ miles up, Mrs. Mary Amburgy has a 6-yard entry with the following section:

Amburgy Coal.

Massive sandstone	15 ft.
Coal	6″
Shale	1″
Coal	18″
Black slate	2″
Coal	2″

Altitude, 1095.

Fifteen feet of thin bedded sandstone down to the creek, underlies the bottom clay of this opening. Again there is a change of covering to massive sandstone, which continues till it goes below drainage a half mile farther up this fork.

At ⅝ mile up is a left fork. On the left of this, ⅛ mile up it, Hiram Pratt has a 10-yard wet entry with the following section:

Fire-clay Coal Rider.

Sandstone	3 ft.
Shale	2 ft.
Coal	1″
Shale	3″
Coal	4″
Shale	3″
Coal	23″
Shale	1″
Coal	22″

Altitude, 1350.

Other openings into this or adjacent beds have been made on this fork, but none were in condition to measure when visited. Strata rise rapidly up stream.

On the right fork and left of the branch and road to Little Carr, 1/8 mile from the gap, 1¼ miles from Carr fork, is Seymour Amburgy's 30-yard entry into 37 inches of the main seam of the Fire-clay coal bed, at altitude 1375. The floor is black jack and a foot of coal is reported under the parting. Ten feet of shaly sandstone is exposed over the entry.

On the right, 1¼ miles up the main right fork, W. B. Smith has a wet entry into the Whitesburg bed, at altitude 1375, having 37 inches of clean coal under 5 feet of shale.

Above the preceding is an 8-yard entry with the following section:

Fire-clay Coal.

Shaly sandstone.	
Shale	2″
Coal	5″
Shale	1″
Coal	15″
Mother coal	¼″
Coal	12″
Flint clay	5″
Coal	9″

Altitude, 1405.

This entry has been abandoned in favor of the one below it. The flint fire-clay here is black instead of the usual brown.

On the left of a left branch 20 miles up Carr, ¼ mile up the branch, George Kelly has an opening into the Fire-clay coal, probably, at altitude 1300, giving 32 inches of coal on a black jack or black slate floor and under 5 feet of shale.

BRANHAM CREEK.—On the left 19¾ miles up Carr: Altitude of mouth, 1085.

On the right at Ambrose Amburgy's, ⅛ mile up the creek, is an opening into the Amburgy bed at altitude 1115 which is duplicated in the following section from a 4-yard entry at altitude 1,125, on the left of a right branch ¼ mile up the creek. The section is:

Amburgy Coal.

Sandstone	10 ft.
Coal	4″
Black slate	1″
Coal	20″
Black slate	1″
Coal	3″

Altitudes, 1115 and 1125.

Ten feet of massive sandstone underlie this coal, and under that is 15 feet of shale carrying bastard limestone boulders.

On the left, ½ mile up, Wiley Tolliver has an 8-yard wet entry into the Fire-clay coal or rider as given in the section following:

Fire-clay Coal Rider.

Shale	5 ft.
Black slate	2″
Clay	1″
Coal	41″
Black slate	3″

Altitude, 1340.

The black slate floor, the bottom of which was not reached, seems to fix the bed as of the rider, and the coal itself has a more defined cleavage than the Fire-clay coal usually shows in this field. The two inches at the top is somewhat slaty. The Isom Sloan coal given in Bulletin No. 11, page 110, is the same as this, but was not exposed here.

BENTLEY FORK.—On the left, ¾ mile up Branham creek: Altitude of mouth, 1125.

In the branch at its mouth is a coal, probably thin, under 30 feet of shale.

On the left of a left hollow, ½ mile up, John Bentley has a closed entry at altitude 1285, showing a coal bed 3 to 4 feet thick under thin black slate as in the Tolliver entry just preceding. Eight feet of shale and a foot of sandstone overlie the slate. The same covering is exposed over an abandoned entry, at altitude 1265, on the right at the head of the fork, ⅝ mile up it.

On the left, ⅞ miles up Branham, Washington Francis has a closed entry into a 3-foot coal bed with 10 feet of sandy shale above it, at altitude 1330. This is probably of the Fire-clay coal, the rider showing in an old prospect 20 feet above it.

WALNUT FORK.—On the left 1⅜ miles up Branham: Altitude of mouth, 1160.

On the left of this fork, ¼ mile up it, Lewis Cook has two entries, at altitude 1325, into clean coal 48 inches thick at the mouth, 45 inches 8 yards in, on a foot of common fire-clay and under 15 feet of sandstone. Its altitude is indicative of the Fire-clay coal bed, but with other beds close to it this is quite uncertain.

On the left, ½ mile up, Nathaniel Bentley has a 4-yard entry into the Fire-clay coal, at altitude 1345, giving 34 inches coal on 3 inches or more of flint fire-clay and under 10 feet of massive sandstone.

On the right of the left branch opposite the mouth of Walnut fork, ¼ mile up it, Nathaniel Bently has a 20-yard entry, at altitude 1315, with 35 inches of coal on what appears to be black slate, shale with calcareous concretions lying close below. "Draw slate," 4 inches thick covers the coal, on which is 8 feet of shale (making a good roof) and 5 feet of sandstone. The coal looks like Fire-clay coal, and it is not unlikely that on reaching greater depth than was practicable the black slate may prove to be black jack.

On the left of a right hollow, 1¾ miles up the creek, Hugh Anderson has a 10-yard wet entry with 39 inches of coal (the bottom 8 inches not seen) under 10 feet of massive sandstone. Its altitude is 1315, and this with its roof indicates the Fire-clay coal bed.

On the left, 2 miles up, R. B. Reynolds has a closed prospect, probably into the same bed, at altitude 1340. This is 1/8 mile northeast across the ridge from the low gap through which the road to Hindman passes.

On the right 2¼ miles up and 50 feet above the creek, John Sparkman has a 15-yard entry at altitude 1355 into 34 inches of coal under 5 feet of sandstone. The floor appears to be of flint fire-clay but was not positively proven.

The numerous openings on this creek would probably suffice for correlation were they fully developed, but under present conditions this can not be done satisfactorily. The most important conclusion reached is that the Fire-clay coal rider may be the best bed on the creek, but that it has not been opened above Bentley fork. Nothing was seen of the Whitesburg bed.

MALLET FORK.—On the left, 21⅜ miles up Carr. Altitude of mouth, 1095.

At the creek ¼ mile up it, is 6 inches of coal, with 6 inches parting, at altitude 1125, under 20 feet of shale. This shale, in greater part, continues to the Amburgy coal bed about 30 feet higher.

This bed has, on the left, ½ mile up the creek, the following section:

Amburgy Coal.

Massive sandstone	10 ft.
Coal	3"
Black slate	1"
Coal	13"
Black slate	1"
Coal	4"

Altitude, 1180.

SHOP HOLLOW.—On the right, ¾ mile up Mallet fork.

On the left, ⅛ mile up the hollow, is 24 inches of coal with 2 inches black slate parting 4 inches from the top and with sandstone roof. Its altitude is 1190 and it seems to be a remnant of the Amburgy bed.

On the right of a right drain, ⅛ mile up hollow and drain, each, Samuel Williams has a 3-yard wet entry with the following section:

Whitesburg Coal.

Shale (changing to thin sandstone at bottom)	5 ft.
Black slate	1½ ft.
Coal	4"
Shale	2"
Coal	1"
Shale	18"
Black slate	3"
Coal	2"
Shale	3"
Coal	23"
Shale	2"
Coal	14"

Altitude, 1395.

The Amburgy coal is apparently thin in a rock house at the mouth of a right branch, 1 mile up, at altitude 1195.

On the left, ⅛ mile up a left branch, 1¼ miles up the creek, Mrs. S. Sloan has a new entry beginning, beside a closed one, from which the following section was obtained:

Fire-clay Coal.

Sandstone	1 ft.
Coal	45"
Black jack	3"
Flint clay	3"
Coal	10"
Shale	1"
Coal	6"

Altitude, 1380.

At the forks, 1⅜ miles up the creek and in it, is 10 inches of coal and shale, covered by a foot of shale with calcareous concretions, at altitude 1225.

On the left, ⅛ mile up the left fork, 1⅜ miles from Carr, E. J. Short has a wet entry into a coal bed, probably the Fire-clay coal, though the roof is quite different to that usually found, as shown by the following:

Fire-clay Coal. (?)

Sandstone	5 ft.
Shale	2 ft.
Coal	1"
Shale	3"
Black slate	2"
Shale	8 ft.
Coal bed	4 ft.

Altitude, 1385.

HAYES BRANCH.—On the left, 21¾ miles up Carr fork.

Again on this branch at its mouth appears the 6 inches coal with 6 inches parting at altitude 1,125, as on Mallet fork.

On the left, ⅛ mile up the branch, is the following:

Amburgy Coal.

Sandstone	5 ft.
Coal	4"
Cannel slate	1"
Coal	17"
Black slate	3"
Coal	3"

Altitude, 1145.

On the right, ¼ mile up, the Whitesburg bed, at altitude 1285, is reported 1½ feet thick. At the head of the right fork of the branch, on the right, ¼ mile from Carr, Lib. Hayes has a 3-yard entry into the Fire-clay coal, at altitude 1310, having 36 inches of coal on 10 inches of black flint fire-clay and bony coal, in about equal parts, and under 4 feet of soft clay shale, as it appears at the mouth of the entry.

On the left of a right branch of Carr fork opposite Hayes branch, Nelson Hayes has opened the Amburgy coal with section about the same as it was found on Hayes branch and at the same height, 1145.

On the left of a left branch, at its head ¼ mile up, 21⅞ miles up Carr fork, Robert Bates has a 20-yard entry into the Fire-clay coal with southerly dip, at altitude 1340 (or higher). It has 37 to 39 inches of coal on a black flint fire-clay floor, and under 6 feet of shale.

On the left of Carr fork, and the road, 22 miles up Carr, the Amburgy bed is opened in a rock-house with

20 inches of coal and a black slate parting 9 inches thick, 2 inches from the bottom. More coal may be under this. Its altitude is 1190.

WILLARD BRANCH.—On the right, 22⅛ miles up Carr. Altitude of mouth 1125.

On the left of a left branch, ½ mile up Willard, ¼ mile up the branch, F. H. Thomas has an entry into the Fire-clay coal, at altitude 1400, having 39 inches of coal, flint fire-clay floor, and roof of 2 feet of shaly sandstone under 4 feet of massive sandstone.

On the left, ¾ mile up the creek, the Amburgy bed is exposed, under a 10-foot massive sandstone cliff, with 27 inches of coal and 2 inches black slate parting, 7 inches from the top, its altitude 1190, 10 feet above the creek.

On the left, a mile up the creek, John B. Smith has a 15-yard entry at altitude 1390; and on the left of the middle head, 1¼ miles up, Marian McIntyre has an entry at altitude 1400. These are of the Fire-clay coal with sections as follows:

Smith.		McIntyre.	
Shale	5 ft.	Shale	5 ft.
Coal	34″	Coal	31″
Flint clay	4″	Flint clay	7″
Coal	4″	Coal	5″

In the McIntyre entry the full thickness of the bottom coal may not have been obtained. The flint clay there is black.

On a left branch, 22½ miles up Carr fork, the Amburgy coal shows at altitude 1220, but its section is not exposed.

On the right of the branch, ¼ mile up it, Grant Honeycutt has an 8-yard wet entry into the Fire-clay coal at altitude 1405. The main seam of coal is 36 inches thick and has regular cleavage. Under it is about 4 inches of black jack and probably more coal below that. Five feet of shale is exposed over the opening.

On the right 22¾ miles up Carr, at the head of a hollow, N. G. Sturgill has a wet entry with the following section:

Fire-clay Coal.

Shaly sandstone	5 ft.
Coal	35"
Parting	5"
Coal	5"

Altitude, 1440.

The parting is a mixture of black jack and flint fire-clay.

NEALY BRANCH.—On the left 23 miles up Carr. Altitude of mouth, 1125.

On the left of a left hollow, 3/8 mile up this branch, William Franklin has an 8-yard wet entry giving the following:

Fire-clay Coal.

Sandstone	10 ft.
Coal	35"
Flint clay	4"
Bone coal	2"
Shale	6"
Coal	6"

Altitude, 1420.

The bottom coal was not seen and it, with the coal above it, were measured approximately.

In the branch on the left, 3/4 mile up Nealy, 5 inches of coal, under 15 feet of shale, lies at altitude 1190, and on the right, 1/8 mile up, is the following:

Amburgy Coal.

Sandstone	10 ft.
Coal	10"
Clay	1"
Coal	4"
Shale	3"
Coal	3"

Altitude, 1215.

On the left fork of this left branch, 3/4 mile from Nealy, are two abandoned entries, with a third just started, into the Fire-clay coal at altitude 1405. The bottom coal and flint fire-clay are there, but were not open to measurement. The main coal seam is 37 inches

thick and has normal cleavage planes. It has 5 feet of shale covering.

At the same distance from Nealy up the right fork of this branch, is a 15-yard entry on the right giving the following section:

Fire-clay coal.

Shaly sandstone	4 ft.
Sandy shale	1½ ft.
Coal	2"
Clay	1"
Coal	36"
Black slate	1"
Fire-clay.	

Altitude, 1385.

Water prevented full examination of the fire-clay floor, but it seemed to be too hard for other than flint clay. That and the character of the roof, which is excellent, both indicate Fire-clay coal. Openings on this branch are on land of Simon Watts.

On the right of Nealy, at the mouth of this branch, James Mullins has a 10-yard wet entry into the Fire-clay coal, at altitude 1410, having about 36 inches on the main coal seam, 4 inches of flint fire-clay and 3 inches of bottom coal, no measurements exact. The roof is 10 feet or more of massive sandstone, under which is 4 inches of coal and slate and 12 inches of weak clay sandstone to the main coal. These 16 inches come down with the coal leaving a good roof above.

On the right, 1¼ miles up Nealy, Elam Pigman has a 10-yard entry into the Fire-clay coal at altitude 1425. The main coal seam is increased from 33 inches two yards in to 36 inches ten yards in. The floor is black jack or black slate. A good roof is given by 21 inches of sandy shale, above which is 2 inches of coal to massive sandstone above the coal.

On the right, 2 miles up Nealy, Mr. Pigman has another entry into the same bed at altitude 1445, giving 38 inches of coal on an inch of soft black slate. Hard black slate and flint fire-clay, 6 inches or more, provide the floor, with possible coal below. A half-foot of clay on the coal and a foot of sandstone on that, the latter inter-leaved with thin sheets of coal, make a bad roof

until they fall. Above them is exposed 7 feet of sandstone, making a good roof.

SPRING BRANCH.—On the right, 23¼ miles up Carr. Altitude of mouth, 1130.

On the left, ½ mile up the branch, 10 feet above it is the following:

Amburgy Coal.

Sandstone	3 ft.
Coal	3″
Slate	3″
Coal	15″
Coal and shale	9″

Altitude, 1255.

On the left, ¾ mile up, George Gibson has a 20-yard entry, and on the left a mile up Arch Gibson has a 12-yard wet entry, both into the Fire-clay coal, at altitude 1450 and 1485, respectively. Their sections follow:

George Gibson.

Sandstone	3 ft.
Coal	35″
Black jack	2″
Flint clay	5″
Coal	7″

Arch Gibson.

Shale	2 ft.
Shaly sandstone	2 ft.
Coal	37″
Hard bottom.	

The bottom coal where seen was perfectly good. In the Arch Gibson entry the roof scales off in thin plates, but nevertheless space 25 by 30 feet is left without props.

On the right, 1½ miles up, Edward Gibson has a 12-yard entry into the Flag coal at altitude 1880. The bed is 6 to 8 feet thick with about 5 feet of coal without parting visible, the remainder covered by falls from the roof, which is an extremely bad one, 10 feet of clay shale showing above the coal. The area of the bed here is small, though a half-mile of outcrop is in sight, with covering nowhere so much as 100 feet deep.

The cliff, 35 feet high, directly under the Hazard bed, shows below the opening; the altitude of its top, 1800.

COLLINS BRANCH.—On the right, 23⅜ miles up Carr. Altitude of mouth, 1130.

On the left, $\frac{3}{4}$ miles up the branch, Russell Collins has a 3-yard entry, at altitude 1355, into a bed with section following, which appears to be of the Whitesburg, though it lies at a considerably greater distance than usual, 140 feet, below the Fire-clay coal rider, and it has not the customary black slate roof:

Whitesburg Coal. (?)

Shale	5 ft.
Coal	25"
Shale	7"
Cannel coal	10"
Block coal	4"

Altitude, 1355.

The cannel coal is of excellent quality, apparently, but it is reported to be explosive in burning. A flag stone quarry lies 40 feet below it.

On the right, $\frac{7}{8}$ mile up up the branch, Green Craft has an abandoned prospect into the same bed (reported thick, but with bad roof) at altitude 1360.

Over this cannel opening is a 5-yard entry with the following section:

Fire-clay Coal Rider

Shale	8 ft.
Black slate	6"
Coal	8"
Shale	28"
Coal and black slate	8"
Coal	27"
Shale	1"
Coal	18"

Altitude, 1500.

On the left of the right hollow, $1\frac{1}{8}$ miles up, $\frac{1}{8}$ mile up the hollow, the Fire-clay coal is opened at altitude 1515. The main coal seam is probably of the usual thickness, about 3 feet, 2 feet being visible. Black jack and flint fire-clay in the dump prove its correlation. It has over it $2\frac{1}{2}$ feet of shale and then 2 feet of sandstone.

On the left, two miles up the branch, the Amburgy coal shows about 2 feet of coal under sandstone, at altitude 1310.

On the left, $2\frac{1}{2}$ miles up, Hazel Collins has a 12-yard entry with the section following:

Fire-clay Coal.	
Shale sandstone	5 ft.
Coal	34″
Flint clay	7″
Coal	13″
Altitude, 1540.	

The bottom coal, as well as the top, is good, and assurance of continued thickness is given by an opening on Buck branch of Rockhouse having 4 inches more coal and 3 inches less parting. The parting here is all black.

On the left of Carr fork, $23\frac{3}{4}$ miles up it, $\frac{1}{4}$ mile from it, at the head of a hollow, Robert Bates has a 5-yard entry as follows:

Fire-clay Coal.	
Sandstone	3 ft.
Coal	37″
Black slate	2″
Flint clay	4″
Coal	5″
Altitude, 1440.	

An inch of bony coal in the middle of the bottom seam impairs its value probably very little. The sticking of an inch of the top coal to the slate under it is likely to be more troublesome.

BUFFALO BRANCH.—On the left, 24 miles up Carr. Altitude of mouth, 1160.

On the right, a half-mile up this branch, Wiley Amburgy has a 12-yard entry, from which the following was obtained:

Fire-clay Coal.	
Sandstone.	
Shale	6 ft.
Sandstone	1 ft.
Shale	$1\frac{1}{2}$ ft.
Coal	37″
Altitude, 1490.	

A knife edge parting, 6 inches from the top of the coal is so unusual as to be almost negligible here.

On the left, 24¼ miles up Carr, is the Alfed Amburgy entry into Fire-clay coal 40 inches thick and 6 inches parting, given in Bulletin No. 11, page 111. That and an entry into the same bed on the opposite side of the creek were both closed at the time of the last visit.

ROARING BRANCH.—On the right, 24¾ miles up Carr. Altitude of mouth, 1210.

On the left, ⅛ mile up this branch, John S. Amburgy has a 5-yard entry at altitude 1475; and on the right of a right hollow, ⅝ mile up, Doctor Sexton has a 10-yard wet entry at altitude 1510. Both are in the Fire-clay coal and their bed-sections follow:

Altitude, 1475.	
Sandstone	5 ft.
Coal	35″
Flint clay	6″
Coal	6″

Altitude, 1510.	
Shale	3 ft.
Massive sandstone	3 ft.
Coal	32″
Black jack	2″
Flint clay	4″
Coal	0

The bottom coal of the Amburgy entry is particularly fine-looking, half of it a rich splint coal. In the second entry the bottom was not seen. There appeared to be about a foot of it.

On the right, 24⅞ miles up Carr, William Amburgy has a 2-yard entry into the top seam of the Fire-clay coal, 36 inches thick, at altitude 1470. The flint fire-clay floor, doubtless, has coal under it. Two feet of shaly sandstone makes the roof.

TURKEY BRANCH.—On the left, 25⅛ miles up Carr. Altitude of mouth, 1275.

In a peak on the right, ¼ mile up a left drain, ⅛ mile up this branch, William Amburgy has a 15-yard wet entry into the Flag coal at altitude 1925. The bed is 6 to 8 feet thick, of which about 2 feet was invisible, mostly block coal, but with a little splint. Fifteen feet of soft argillaceous sandstone covers the bed, and a hard sandstone caps the peak, which carries the only area of the coal.

WILDCAT BRANCH.—On the left, 25⅜ miles up Carr. Altitude of mouth, 1295.

A rock-house on the right at the mouth of this branch gives the Amburgy coal at altitude 1300, just before it goes below drainage on Carr fork.

On the left, ⅛ mile up the branch, the Fire-clay coal rider (probably) is opened in an 8-yard entry at altitude 1500. Sections of these two beds follow:

Altitude, 1300.

Sandstone	10 ft.
Coal	2"
Shale	1"
Coal	12"
Shale	7"
Coal	1"
Shale	1"
Coal	1"
Sandstone.	

Altitude, 1500.

Sandstone	6 ft.
Coal	17"
Knife edge parting.	
Coal	7"
Clay	1"
Coal	4"
Clay	2"
Coal	10

The bottom of the higher bed was not seen and there may be a little more than 10 inches of coal in that seam.

In a cliff on the left of Carr, rising from it at 25½ miles up, is 30 feet of shale upon which is as much more sandstone, all overlying the rock house sandstone covering the Amburgy coal.

On the left branch of Carr, 26¼ miles up it, which gives a road to Beaver creek, on the left of the road and right of the branch, ¼ mile up it, Wilburn Honeycutt has a 12-yard wet entry into the Fire-clay coal at altitude 1505. The main seam of the bed appears to be 3 to 3½ feet of coal without parting. The flint fire-clay is below and 2 feet of shale under 4 feet of sandstone is exposed on top of the coal.

On the right, 26⅜ miles up Carr, Wiley Amburgy has a 20-yard entry with the following section:

Fire-clay Coal.

Sandstone	5 ft.
Coal	36″
Flint clay	6″
Coal	14″

Altitude, 1515.

In a right branch, 26⅝ miles up Carr, ⅛ mile up the branch, is 10 inches of coal on sandstone and under sandstone 15 feet or more thick; its altitude 1435. Beside the branch, ¼ mile up it, the Whitesburg bed is exposed, at altitude 1505, with the section following. On the left, ⅜ mile up the branch, 20 feet above it, is Grant Honeycutt's 8-yard entry into the Fire-clay coal, at altitude 1535, with the section following:

Whitesburg Coal.

Shale.	
Coal	10″
Black slate	1″
Coal	2″
Fire-clay	6″
Covered	1 ft.
Sandstone	3 ft.
Black slate	2″
Coal	1″

Fire-clay Coal.

Sandstone	3 ft.
Coal	33″
Black jack	4″
Flint clay	3″
Coal	11″

Two inches of the bottom of the Fire-clay coal bed has a slightly bony appearance, but is probably harmless.

On the left, 27¼ miles up Carr, Watson Adams has a prospect into the Fire-clay coal at altitude 1615, giving the section following. On the right, in part, and partly in the creek 27½ miles up Carr, at Omaha post-office, Green Collins has an opening into the Fire-clay coal rider at altitude 1660, its section following:

Fire-clay Coal.

Sandstone	8 ft.
Sandy shale	6 ft.
Coal	3"
Shale	½ to 1"
Coal	30"
Flint clay	6"
Coal	10"

Rider.

Shale	8 ft.
Black slate	8"
Coal	4"
Shale	1"
Coal	2"
Shale (with coal)	9"
Coal	2"
Shale	1"
Coal	16"
Coal (?)	36"

The bottom seam of the Fire-clay coal has no bone in it. The bottom 3 feet of the rider being in water was not seen. The 2 feet that was felt appeared to be all coal.

The following notes are of coals above Carr fork to Bull creek, including the latter, all on the east side of the river.

On the right of left fork of a branch ½ mile above Carr, at its head a mile from the river, Elijah Combs has an entry, at altitude 1485, into good hard block coal, 37 inches thick, under 8 feet of shale. A foot or more of coal is reported under about a foot parting now serving as floor for the entry. With the ridge 200 to 300 feet higher a considerable area of this coal is available. It is of the Flag bed, the Fire-clay coal being at altitude about 1100.

Desultory prospecting reported in this vicinity has failed to bring to light any other satisfactory coal, and no other opening was found below Felix branch, 3¾ miles above Carr fork, and 1¾ miles above Masu station at the mouth of Mace's creek.

On the right of the left fork of Felix branch, ¼ mile from its mouth, Felix Brashear has an 18-yard entry

with the following average of a somewhat variable section:

Fire-clay Coal.

Sandstone	15 ft.
Shaly sandstone	5 ft.
Coal	32″
Black jack	8″
Flint clay	3″
Coal	13″
Black slate	2″

Altitude, 1065.

The bottom coal is a good hard block coal.

On the right of the right fork, ⅜ mile up the branch the top coal is 38 inches thick, the rest of the bed hidden; its altitude is 1050, about 165 feet above the river.

On the left, ½ mile up a branch 2¼ miles above Masu, Nathaniel Brashear has a 15-yard entry with the following section:

Fire-clay Coal.

Shaly sandstone	5 ft.
Coal	39″
Flint clay	5″
Coal	5″
Black slate	5″
Shale	4″
Coal	8″

Altitude, 1100.

Only the top seam of coal is taken out.

At 2¾ miles above Masu, 23 inches of coal was taken from an entry, now closed, at the level of the railroad track, altitude 910. This coal shows near the bottom of the following section from the mouth of a branch 3¾ miles above Masu and ½ mile below Big Branch:

Sandstone	40 ft.	
Covered shale and sandstone	20 ft.	
Shale	25 ft.	
Coal	12″	Amburgy Coal. Altitude, 945.
Shale	8″	
Coal	1″	
Shale	3″	
Coal	3″	
Fire-clay	1 ft.	
Sandstone	18 ft.	
Coal	23″	
Fire-clay	3 ft.	
Sandstone to track level	2 ft.	

The Fire-clay coal is exposed, slipped so that its measure could not be taken, in a rock-house, ½ mile up the branch, at altitude 1155.

BIG BRANCH.—Hombre station, 6 miles above Carr fork. Altitude of mouth, 905.

On the right of a left branch, ¾ mile up Big branch and ½ mile up the left branch, Sampson Brashear has an 8-yard entry with the following section:

Sandstone	15 ft.
Coal	29″
Flint clay	4″
Coal	15″

The bottom coal here is all good.

On the right of the left fork, at the forks of the creek 2½ miles from the river, the following is exposed, giving a section from the creek probably about up to the Whitesburg bed:

Sandstone	10 ft.
Shale	10 ft.
Sandstone	2 ft.
Coal	5″
Shale and coal	9″
Coal	6″
Fire-clay	1 ft.
Shale to water level	4 ft.

Altitude, 1145.

On the right and left, 3½ miles up, Thomas Fields has a 4-yard entry and exposure in a rock-house of the Fire-clay coal, at altitudes 1230 and 1235, giving 24 and 31 inches, respectively, of coal in the main seam. Apparently there is no coal under the flint fire-clay. To that clay taken from the entry a little of the coal adheres and so is lost.

On the right, 3⅝ miles up three entries at altitude 1240 give 32 and 36 inches of coal over black jack and flint fire-clay and common fire-clay next the flint. The coal thickens up stream, but no more openings have been made further up to see if the increase continues. The last entries are about 20 feet above the creek.

On the left of the river, ⅛ mile above Hombre, Richmond McIntyre has a wet entry at altitude 1120, in which the top coal is 24 inches thick, and the bottom coal perhaps as much. Five feet of shale lies on the bed.

FORD BRANCH.—One mile above Hombre. Altitude of mouth, 915.

On the left of the mouth of this branch Ellett McIntyre has a wet entry into the Fire-clay coal at altitude 1135, and on the left at the forks, ½ mile up the branch, is a 7-yard entry into the same bed at altitude 1155, in the point of a hill and hardly under solid roof. These give the following sections:

Altitude, 1135.

Shale	2 ft.
Black slate	2 ft.
Coal	21″
Flint clay	4″
Coal	21″
Fire-clay	1 ft.

Altitude, 1155.

Earth.	
Coal	23″
Flint clay	4″
Coal	18″

On the right fork of the left fork, from 1½ to 2 miles up from the river, on land of Solomon Caudill, the following section was obtained, the Hindman bed show-

ing on the left at the head of the branch, the bed next below being opened close by:

	Altitude.
Ridge tops, about	1700 to 1750
Hindman coal	1660
Francis coal—33 inches	1600
Flag coal—stain	1560
Cliff under Hazard coal	1480 to 1510
Young coal—reported 30 inches	1470

The comparatively broad tops to the hills of this vicinity give good working area to the Flag coal, which has not been opened, but higher coals are too restricted for other than local use.

On the right, 3/4 mile from the river, at the head of a branch 1½ miles above Hombre, at a closed entry on the Ira Banks farm, the following was obtained:

Hindman Coal.

Broken sandstone.	
Shale	1½ ft.
Coal and shale	1 ft.
Coal	2 ft.
Thin parting.	
Coal.	

Altitude, 1730.

The total thickness is reoprted to be 9 feet and evidently is nearly that, but the small area, bad roof and great height render the bed unattractive.

On the heads of a branch 2 miles above Hombre the cliff sandstone under the Hazard coal lies at altitude 1540 to 1570 and above this is the Flatwoods of the vicinity. Iron ore shows in small quantities at 1590. At 1625 the Flag coal is opened, showing a 3-foot bed with a 1-inch parting in its upper half, the lower half of the prospect being covered. The coal is somewhat slaty, the roof sandstone. The opening is about ½ mile south of that of the Hindman bed just given.

A prospect in the point of a hill midway between the two openings last given shows a thin slaty coal at altitude 1725. This is of the Hindman bed, but the place chosen for opening does not give a fair exposition of

the coal, all but the hard and slaty coal having weathered away.

In the railroad cut at the point of the spur, 3½ miles above Hombre the following is found:

Shale	15 ft.	
Coal	1 ft.	Altitude, 985.
Shale	15 ft.	
Coal	1 ft.	Altitude, 970.
Sandstone	15 ft.	

One or both of these coals, probably the upper, is of the Amburgy bed, close under which is often found a thin coal.

At Cornettsville postoffice, 3¾ miles above Hombre, S. W. Hampton has a 7-yard wet entry with the following section:

Fire-clay Coal.

Sandstone	4 ft.
Shale	7 ft.
Coal	18″
Flint clay	5″
Coal	24″
Black slate.	

Altitude, 1180.

On a left branch at Elijah Sumner's, 4 miles above Hombre, the Amburgy bed has 18 inches of coal, lying on 20 feet of sandstone and under 12 feet of shale in one place and under 3 feet of shale, then 20 feet of sandstone in another adjacent. Its altitude is 975.

On the left, ⅛ mile up the branch the Fire-clay coal has been opened, at altitude 1190, with possibly 3 feet of coal in the upper seam, and additional coal under a 5-inches flint fire-clay parting.

BULL CREEK.—Four and one-half miles above Hombre. Altitude of mouth, 930.

On the left at the mouth of the creek, 15 feet above it, the thin coal under the Amburgy bed shows about 8 inches thick with 15 feet of sandstone above and below it.

On the right a half-mile up the creek and 5 feet above it, the Amburgy bed is exposed, at altitude 985, with 2

feet of fire-clay and then 3 feet of thin-bedded sandstone beneath and 4 feet of sandstone above it.

On the left of a left branch a mile up the creek, 140 feet above it, 1/8 mile up the branch, John Caudill has a 3-yard wet entry, the only opening found on the creek, into the Fire-clay coal. It gives in section:

Fire-clay Coal.

Sandstone	3 ft.
Shale	6 ft.
Coal	26″
Flint clay	4″
Coal	10″

Altitude, 1165.

The bottom coal in water was not measured exactly, and thin cannel coal was reported below it.

On the right 1¾ miles up the creek the following is exposed:

Shale	40 to 50 ft.
Coal	5″
Shale	½ to 1½ ft.
Coal	7″
Shale	1 to 5 ft.
Sandstone in creek.	

Altitude, 1155.

The upper 25 feet of this shale, with large lime boulders in it, rises from the creek on the right, 2½ miles up it. On the shale is coal and black slate at altitude 1220, probably of the Whitesburg bed, the usual sandstone under it having disappeared. This gives a rise of strata up the creek of about 80 feet in 1½ miles.

Opposite the mouth of the large left branch, 3½ miles up the creek, 30 feet of shales still remain above it with 10 feet of sandstone covering them.

At 4½ miles up, 30 feet of shale from the creek appears again with 24 inches of coal at altitude 1380 in it, 20 feet above the creek.

At 4¾ miles up this coal in shale is reduced to 8 inches, at altitude 1410.

At the school house at the forks of the creek, 5½ miles up it, the altitude, as determined by barometer, is 1490.

At the head of the left fork, ¾ mile up from the school house and opposite the Green Combs entry on Montgomery creek, George Field has an 8-yard entry with section similar to that of the Combs entry, as follows:

Flag Coal.

Massive sandstone	20 ft.
Coal	16″
Shale	5″
Coal	40″

Altitude, 1720.

This is all block coal, the lower seam hard. The hill tops are 150 to 200 feet higher and being well rounded in this "flatwoods" region give a fairly good area to the bed.

On the right of the right fork and of the road to Defeated branch, a mile above the school house and a quarter-mile from the gap, James B. Caudill has a pit at altitude 1695, from which has been taken coal said to be 30 inches thick. This is of the Hazard bed, and it is not unlikely that a lower seam of the bed would be struck by sinking the pit a little deeper.

Above the pit is a 2-yard entry into the Flag bed, which here is somewhat farther from the Hazard than is the case where the two have been opened in juxtaposition farther down the river. Its section follows:

Flag Coal.

Sandstone	5 ft.
Coal	16″
Shale	6″
Coal	1 ft.
Shale	13″
Coal	40″

Altitude, 1760.

THE OOLITIC LIMESTONES OF WARREN COUNTY.

BY MALCOLM H. CRUMP.

LOCATION.—These oolitic limestones, so widely used for building purposes, are found skirting the eastern and southern edges of the western coal field in the countties of Grayson, Barren, Warren, Logan, Todd, Christian, Trigg and Caldwell, but the greatest economic and commercial developments on these deposits have been made in the county of Warren in the vicinity of Bowling Green. There are more than 200 miles of outcrop of this stone in Warren county, much of which is readily accessible to transportation by both water and rail. Barren river divides the Warren county field in two parts, with fine exposures immediately on its banks and advantage has been taken of this fact in the location of several quarries.

HISTORY.—The first quarries were opened more than three-quarters of a century ago and the stone taken from them is still to be seen in walls and monuments which have stood the test of time for nearly a hundred years. This tells the story of its durability. The Corinthian columns, with their delicately carved capitols, at the county court house in Bowling Green, are as sharply defined and as perfect as when first completed, although they have been exposed to the action of the elements for nearly fifty years.

GEOLOGICAL POSITION.—All of these oolitic beds of limestone are found immediately below the base of the Chester and usually in a vertical interval of less than 50 feet. The marked topography of the Big Clifty sandstone at the base of the Chester renders the horizon of the oolitic easily found and readily followed.

BEDS.—These are from 10 to 22 feet thick, with probably four workable horizons included within a vertical distance of 150 feet. The beds are usually without seams and often 20 feet thick, without any perceptible change in their appearance or structure from the base of the bed to the top.

Structure.—The grains, or oolites run from one-thirtieth to one-fiftieth of an inch in diameter and are apparently foliated in structure, not unlike the concentric layers of an onion. Their composition is remarkably pure, often running as high as 98% carbonate of lime. Some of the beds when taken from under considerable stripping contain a small percentage of petroleum, which gives the stone a peculiar color and odor. Analysis and experience has shown that this oil carries no perceptible asphaltic base; hence the stone bleaches perfectly white on exposure, the time required for complete bleaching varying from 3 months to as many years, depending on climatic conditions and exposure to the sun.

Economic Features.—The most recent preliminary examinations have shown that from the four horizons mentioned above and in localities which are favorable for immediate development, and transportation, and easily accessible can be obtained commercial stone, amounting to more than one hundred million cubic feet, which means 320,000 cars of 400 cubic feet each. These beds are practically horizontal and well located for economical quarrying. The stripping runs from nothing to 100 feet or more. It can be economically removed to a thickness equal to that of the workable bed; that is 20 feet of stone stripping can usually be removed from a 20-foot bed of workable stone. As many as 48 feet are now being removed in one of the largest quarries, but this is by reason of the fact that the strippings are carried to a convenient crusher, where it is converted into railroad ballast and material for concrete. Eventually all this waste will be converted into merchantable material in the form of ballast, road metal, concrete material and agricultural lime. For the latter there is great demand, and an unlimited territory in the limeless region of the Mississippi valley, where every acre of land needs the application of ground limestone to correct the acidity of the soil. There is among the four horizons mentioned one that deserves special notice, the product from which has recently come before the public and is known as the "Royal White." This bed when first opened shows 15 to 18 feet in thickness. It is snow white with rather large oolites, consisting of

concentric calcite coatings about a somewhat darker center.

The grains or oolites are cemented by an amorphous limestone of the same color and purity. It is especially suitable for carving, as has been fully demonstrated by the actual work of the local stone cutters and carvers of Bowling Green and other places. It analyzes 99.77% of carbonate of lime, and its crushing strength is 9,200 pounds per square inch.

The waste from this bed promises to make a particularly good, stainless Portland cement, for which there is at present a great demand at highly remunerative prices.

This stone has not had the test of time for exterior use, but there is no question as to its value, and beauty, for interior work. It should take the place of the Caen stone of France, which is so much used in the cities of the Eastern seaboard and as far west as Chicago, and which sells for $1.25 to $1.50 per cubic foot.

OPERATING QUARRIES.—There are six of these in the vicinity of Bowling Green, with a combined maximum daily capacity of 10 to 15 cars of 400 cubic feet each, of mill blocks, but they are all working on rather a limited scale, owing to the lack of necessary capital. One million dollars could be economically expended in the opening and equipping of quarries and the construction of mills and of plants for utilizing the strippings and waste material from the quarries and mills. An output of not less than 50 cars daily would be necessary for the proper entrance into the markets of the great cities and building centers of the country.

THE BOWLING GREEN WHITE STONE COMPANY, which quarries and sells the Bowling Green white oolitic limestone, is the pioneer producer in this section, and designates its product as "The Aristocrat of all the Limestones." This company claims for the stone they produce the following characteristics:

1. Beauty of color and uniformity of texture.
2. Great strength.
3. Unexcelled durability.
4. Ease of working.
5. Resistance to discoloring influences.

6. High resistance to the action of heat, cold and moisture.

The color of the stone is a rich creamy white, without the dead appearance of many oolitic limestones, or the hard, glossy glare of the marbles; while uniform in color, it presents a sufficiently varied appearance to avoid any resemblance to artificial stone. Its strength is amply sufficient for all the modern requirements, as may be seen by the following official report of the Federal Government, made by Maj. J. M. Reilly, of the Ordinance Department, U. S. A. Three samples from these quarries were tested with the following ultimate crushing strength per square inch: 6,532, 7,009 and 6,746 pounds. This shows a strength far in excess of any weight that would be imposed upon it by any build ing or other structure of the present time, or probable future. There is no stone used in building in this country which has been subjected to a more severe test as to durability and resistance to the disintegrating influence of atmospheric and climatic changes than the Bowling Green oolitic limestones. More than a century ago, stone was taken from this original quarry, now being operatel daily by this company, and used in a primitive way for hearthstones and chimney caps, and many of these are still to be found in use today in different parts of Warren county. They are perfectly intact and absolutely free from any indications of disintegration or other signs of decay. There are buildings, walls and monuments in Bowling Green more than 100 years old, which stand today with tool marks upon them as delicately clear and distinct as when they first came from the chisel. The original quarries have been actively and continuously operated for more than 75 years, and yet the supply is apparently inexhaustible, a total area of less than ten acres having been worked in that time. The beds in this quarry are 22 feet thick, from which an overburden or stripping of 45 or more feet is being re-worked, and disposed of practically at cost. Owing to the uniformity of texture, this stone admits of the finest carving and hence is in great demand for monumental purposes; it may be split to such advantage that a curved surface of 100 degrees may be obtained without risk of the line of fracture crossing the

curve. The small amount of petroleum in the stone rapidly bleaches out and leaves that creamy white surface, so much admired and desired. This bleaching out of the petroleum is due to the fact that there is no residual asphaltic base. All the quarries in this vicinity show more or less of this oil after the stone gets under heavy cover, and but little of the stone shows the ultimate whiteness when first quarried. There is one exception to this rule, viz: the "Royal White." This company from its quarries, is fully prepared to undertake the delivery of stone of pure white color in any desired quantities on short notice. It is now more than one year ahead in its stripping and has 100,000 feet of stone channeled, and its annual output equals to, and probably exceeds, that of all the other operating quarries in the Bowling Green district. Its quarries and mill are equipped with the most modern and complete machinery obtainable, and no pains are spared to meet the requirements of the most discriminating taste. Medals were given to this product at Chicago in 1893, St. Louis in 1904, and at other places. Prof. Wm. S. Day, of the U. S. Geological Survey, says: "The product of the B. G. White Stone Company of Kentucky is deserving of special notice, because of its peculiarities and its value as a building stone. It is quite similar in analyses and structure to the celebrated Portland Oolite of England, as shown by the following analyses:

Analyses.

	Bowling Green	Portland, Eng.
Carbonate of Lime	98.30	95.16
Carbonate of Magnesia	1.12	1.20
Silica	1.42	1.20
Iron and alumina	0.39	0.50
Water and loss	1.75	1.94
	100.00	100.00

This stone is known commercially as Bowling Green White Oolite. It is quite different in character from the oolitic stone of Bedford, Indiana, the constituent oolitic grains in this stone being larger and distinct, whereas in most Indiana stone they are minute. The local quarries are of large extent and well equipped with

channeling machinery, derricks, etc. These beds were first opened in the year 1833, and the product has been shipped throughout the country, ranging from Maine to Florida. Among the cities in which it is most used are New York, Philadelphia, Washington, Baltimore, Louisville, Nashville, Memphis, Bowling Green, and to some extent, Chicago. The stone is soft and easily worked, and, like the Indiana stone, hardens on exposure to the atmosphere. Carvings made upon it stand perfectly and its color under the influence of sunlight tends to become continually lighter. When heated to redness on the surface, and plunged into cold water, it revealed no crack, even upon examination with a magnifying glass, and in some cases on being reheated a second time and plunged into water, still failed to present any evidence of cracking."

John Longworth, superintendent of construction of the $125,000 Federal Building at Bowling Green, Ky., states "that during the past six years, while employed for the U. S. Government, it has frequently been my duty to make inspections of limestone coming from the Bowling Green quarries. It gives me pleasure to state that I have always found this stone to be fully up to the standard required by the specifications. When delivered it is generally unsightly in appearance and color, owing to its being saturated with oil, but I can vouch for the fact that these oil stains bleach out, leaving a clear, uniform white appearance. The Bowling Green stone is of very fine texture, imperious to water, and I believe is the finest building stone in the country." Architects and contractors speak equally well of it, using such expressions as the following: "It stands all kinds of weather, and is adapted for any use such as buildings, monumental work, curbing, flagging, bridge building, etc." Another says: "For beauty and expressiveness of color, for durability, for carving and highly decorative work, I consider this stone unsurpassed by any limestone and better in most cases, than many classes of costlier stone."

THE BOWLING GREEN WHITE STONE COMPANY.—This company owns 250 acres of oolitic stone, twenty-one feet thick, with an average of 35 feet of strippings. Its output for 1912 was 102,000

cubic feet. The estimated and expected output for 1913 is 150,000 cubic feet. It owns and operates three channelers, only two of which are in active operation at this time. It has one derrick for quarrying purposes and one for stacking. About fifteen men are constantly employed in the building stone quarry, and about fifty men in stripping and crushing the overburden, which is a separate operation. Two steam drills are used in the building stone quarry and three in the stripping department, in addition to one four-inch well drill. There is a mill of eight gang saws, one New Albany planer, one thirty-ton steam traveller with a fifty-foot, elevated tramway, one air compressor and one air hammer. There is also one number 6 Gates gyratory crusher, with a capacity of two hundred and fifty tons of crushed stone per day, and one Jeffreys pulverizing mill for granulating limestone for agricultural uses, capacity fifty tons per day. The output of the crushing plant for 1912 was 33,000 cubic feet. One Sullivan channeler is used, also one Wardwell; the latter is in active use at this writing. The manner of working is as follows: The stone is first channeled and then drill holes are put under the channeled blocks; slips and wedges are then put in these drill holes and driven in, which raises the stone and loosens it from its floor, or bedding. The stone is then turned on its side by means of derrick dogs, which are connected with a thirty-ton steel derrick. The steam drills are used to fashion the stone into sizes readily handled. They are then ready to load on the cars, which run directly into the quarry. The stone for mill use is placed on a tram and lowered to the mill by gravity. All the stone is shipped directly by rail. The cost of loading runs from two to five dollars per car for the mill blocks, and from five to seven for sawed and dressed stone. The drainage is by means of steam jets. This stone resembles other oolitic limestones in texture, but varies in color. When first taken out it has a brownish look, caused by the presence of petroleum, but it bleaches white after a few months exposure to the air. It occasionally contains flint streaks and sometimes iron streaks, some of which will "bleed" after quarrying. The thickness of the overburden that can be reworked and wasted is equal to the thickness of the commercial

stone, but in this particular quarry the stripping is sold as stated before, for ballast, concrete, etc., and the proceeds from the sale of the crushed stone, etc., pays for the entire stripping and some years shows a profit. At present the mill waste is not utilized, but could be made to pay if converted into lime. Tests of this have been made and the product was a lime of very high grade. The principal markets for this building stone at the present are in Kentucky and Tennessee cities and towns. Lately much of it has gone to New York City, Philadelphia and some to Chicago. The mill block trade is found most profitable for this quarry. Among the noted buildings recently erected using this stone are St. Thomas' Episcopal Church, 55th Street and Fifth Avenue, New York City; Federal buildings at Gulfport, Miss.; Hotel Halcyon, Miami, Fla.; First Christian Church, Louisville, Ky.; A. M. Lothrop residence, Washington, D. C.; Alfred E. Burke residence, Philadelphia, together with many Federal and other business buildings in many parts of the country. Thirty-three buildings for the Peabody Normal College, Nashville, Tenn., are now under construction and using this stone. Alongside of this quarry, and forming practically a portion of the same, is the Oman White Stone Company, which owns sufficient stone to last many years, and is fairly well equipped with the requisite channelers, derricks, etc., together with a mill from which much finished stone has been shipped. It is further equipped with electric derricks, and diamond saws in addition to gang saws. Some of the largest contracts ever handled here have been undertaken by the operators of this enterprising quarry. The manager is a veteran from the quarries of Scotland, who has grown up in the business and is quarryman both by birth and tradition. The Bowling Green and Green River quarries are located on Barren river, about five miles north of the last mentioned quarries, and have been in operation about five years. There are 175 acres of good oolitic limestone which has a commercial thickness of 16 feet with an average of 12 feet of stripping. The output for 1912 was 94,000 cubic feet, and the estimated output for 1913 is 150,000 cubic feet. It operates one 25-ton, one 15-ton and two 30-ton derricks, all operated by steam. There are two Wardwell

steam channelers and three gasoline channelers, together with four air drills and two compressors. An average of 60 men are employed at the quarries and the mill. The mill is 45 feet by 80 feet, with four gang saws and one diamond saw 48 inches in diameter, with 50 teeth. There is one 14 foot by 36 inches by 30 inches open side planer. In addition the company operates one and a half miles of narrow gauge railroad from the quarries to the shipping point on Barren river, whence the stone is barged some eight miles to the mill on the L. & N. R. R. at Bowling Green. There is one 15-ton steam derrick at the river terminus of the narrow gauge road and one of 30 tons at the mill. The mill also contains one air compressor, and one air drill. Much of the product of this quarry goes to Nashville and Memphis. The stone for the $125,000.00 Federal building in Bowling Green came from these quarries and speaks most forcibly for the character and beauty of the product.

The Murphy Bros. quarry is located between the above quarries and is a continuation of the 16-foot bed. This is among the latest, and most enterprising of the quarries, and is well equipped with all the requisite derricks, together with 3 channelers and a spur of the narrow gauge railway above mentioned. There is no mill connected with the quarry, the output being disposed of as fast as quarried in the shape of mill blocks. The capacity is about ten cars per week of superior stone with more than 100,000 cubic feet in sight.

THE VICTORIA LIMESTONE COMPANY.—This company is located at Slim Island, on Barren river, about two miles in an air-line from the last mentioned quarries. The actual working face is about 150 feet above low water, to which the product is handled by gravity to barges by means of a railroad 500 feet long. The company owns 45 acres of good stone. The thickness of the face or bed where the quarrying is now going on is 22 feet and the stone is of the same general texture and color as in the other quarries mentioned; 18 feet of the 22 are considered commercial stone and the face is exposed for 2,500 feet. The average stripping for the first 100 feet back from the face is estimated at 25 feet. The output for 1912 was 67,000 cubic feet, and for 1913 the estimate is for 100,000 cubic feet. There are three

steam derricks of 25 tons capacity, one Ingersoll 8. Y. channeler, with a capacity of 12,000 cubic feet of commercial stone per month. There are in addition three steam drills; 28 men are employed at this time. The mill building of the Victoria Limestone Co. is 45 by 90 feet and its equipment consists of one 200 by 50 foot steel crane runway with a traveling crane of 25 tons capacity, electrically operated, two gang saws of the New Albany Manufacturing Co.'s make, one double blade diamond saw, blades 76 inches in diameter, containing 140 diamonds each; one double side New Albany planer, one stone lathe with a capacity for columns of 25 feet in length with bases 7 feet in diameter, and one Ingersoll Rand air compressor, capacity 76 cubic feet per minute, which is amply sufficient for 6 pneumatic tools.

The shipping from this quarry is by barge to the elevator at Bowling Green, a distance of nine and one-half miles, and thence a short distance by rail to the mill. No pumping for drainage is necessary so far as quarry operations are concerned, but water is brought from the river to the quarry and for the use of the boilers by means of a number 4 Cameron pump. The general character of the stone is identical with that of the vicinity except that, owing probably to its southwest exposure, less oil is found and hence less discoloration as it comes from the quarry. It is beautifully white when it comes from the planer. The quarry operations so far have shown only two irregular streaks of flint, and these at rare intervals, and no crows feet have been met with, except at the extreme bottom of the 18-foot ledge. It is estimated that stripping to the deph of 40 feet can be profitably removed, without using the by-product. It is further estimated that the quarry waste will equal 20 per cent and the mill waste 10 per cent, which is considered about normal. As yet no means have been adopted for utilizing the quarry waste, but the mill waste is being used for rubble foundation work. The most profitable market is in the South, West and Southwest, where the freight rates are more favorable, in comparison with those charged from the Bedford district to Northern and Eastern markets. The stone for the new governor's mansion at Frankfort, Ky.,

came from this quarry, as well as that used in churches and residences in Knoxville, Memphis, Jackson, Tenn., Bowling Green, Ky., and other points.

THE CADEN QUARRY.—This is located 10 miles northwest of Bowling Green on Gaspar river, about one mile from its entrance into Barren river. This company has been in successful operation for 40 years or more, and is fully equipped with all needed machinery. Its mill is in Evansville, Ind., to which place much of the product has gone by barge via Barren and Green rivers, a distance of 180 miles. A large part of the product of this quarry has been and is now used for monumental work. Many residences and commercial buildings are to be seen in Evansville built from stone from this quarry. The Betz building of Philadelphia, Pa., is a notable example of its superior quality and excellence.

There are many places along the 210 miles of outcrop in Warren county where this stone can be profitably opened and successfully operated. Some of these points are immediately on the ever navigable waters of streams with a low freight rate via Barren and Green rivers to the Ohio river, thence to the Mississippi and the ocean and the Panama Canal. It is claimed that a rate of 25 cents per hundred pounds can be had via Pensacola and sailing vessels to the Hawaiian Islands and the California coasts, and this rate will be materially reduced when the Panama Canal is in operation. There is a steady and constantly increasing demand for this stone, and the quantity used is limited only by the output. Capital is the one thing needed and this will certainly come at an early day. The supervising architect of the U. S. has recently made a personal inspection of the quarries and expressed himself as much pleased with the stone, as well as with the quantity in sight. Representatives of such leading architects as Carrere and Hastings, and Cram, Goodhue and Ferguson, of New York City and Boston have also carefully inspected the quarries and the facilities for production, with the view of using it in the East. Large operators and contractors from Chicago have also been here, and it is only a question of time until there will be 50 operating quarries with an output of 100 or more cars daily. The age of wood is passing rapidly. The age of stone and

cement is rapidly approaching, if not already here, and the Bowling Green oolite will be one of the high-grade building and monumental stones largely used.

CONCLUSIONS.

The Bowling Green oolite is similar to the oolites of Indiana in chemical composition, ease with which it is worked and its great durability. It is superior to that in color, in facility for carving and in general beauty of appearance. As it comes from the quarry it is a grayish white, when not containing a noticeable amount of light volatile petroleum, the latter being readily noticeable when present both by its odor and appearance. After a short exposure and before placed in the wall it bleaches to a creamy white, which grows whiter with age, instead of darker, as is the case with so many oolites, especially those which weather in such a way as to leave small imperceptible holes, and a porous surface into which soot and other impurities are driven which discolor the surface of the stone. For the first 15 to 30 feet in from the face as the ledge is worked the stone is perfectly bleached, no trace of oil being noticed. On all western exposures the white stone is found. Perfectly white stone can always be secured by allowing the quarried stone to remain on the yard 2 to 6 months. There is much demand in the Eastern cities for a bleached stone which can always be supplied, though at a somewhat higher price because for the above reason it must be carried on the yard for some months. This bleached stone sells for 10 to 15 cents per cubic foot higher than the fresh or unbleached product. The estimated annual output, which includes scabbled stone as well as mill blocks for the year 1913, is 150,000 cubic feet, valued at $45,000.00, which means an average selling price of 30 cents per cubic foot. The sawed stone will probably average 100,000 cubic feet per annum, worth $80,000.000, the average price for sawed stone being 80 cents per cubic foot f. o. b cars at Bowling Green. The freight rate to New Yirk City is 27¾ cents per hundred pounds and other rail points in proportion. The river and ocean rates are much less. The opening of the Panama Canal promises a very low rate to the

west coast of South America as well as to San Francisco and Honolulu.

Following is a statement in regard to Bowling Green stone from Mr. John Longworth, Superintendent of Construction of the Federal Building at Bowling Green, Ky.

CHARACTERISTICS OF BOWLING GREEN OOLITIC LIMESTONE.

The fact that Bowling Green Oolitic Limestone is not extensively quarried accounts for its being less understood by contractors and superintendents than the Bedford and other well known building stones. As a matter of fact it is far superior to the Bedford stone. Lack of capital and transportation facilities account, to a great extent, for its limited output; however, as more quarries are gradually being opened up, it is hoped these difficulties will be cleared away and Bowling Green become a bee-hive of stone industry rivaling that of Bedford.

Bowling Green stone is found in three workable horizons, average fifteen feet each, top layer nearly white, middle layer dark yellowish grey, and bottom bed considerably darker, sometimes almost black, all of which bleaches on exposure to a soft light grey.

It was with considerable misgiving that I allowed the contractor for the Federal Building at Bowling Green, Ky., to use black, white and yellow stone promiscuously throughout the entire building; yet, after ten months exposure, we find most of the dark stone just as white as that which was white when set in place and I am satisfied that in a short time the entire building will be absolutely uniform in color.

A few months ago the writer was detailed to inspect the stone work on the government building at Paducah, Ky., one-half of which was built thirty years ago, the other half five years ago; Bowling Green stone was used throughout. It is impossible to tell from the appearance of the stone which half was erected first; the entire exterior is perfectly uniform in color, a very light grey and the most pleasing appearance of any stone structure the writer has ever seen. While at Paducah I talked with the stone contractor who did the work and he told me a great

deal of the stone used was almost black when put in the wall. Analysis of the stone shows following results:

Carbonate of lime	97.69%
Absorption of water	6.20%
Weight per cubic ft. (dressed)	167 lbs.
Crushing strength per sq. in.	6,167 lbs.

The stone is massive, with no crowfeet, lamination, or bedding planes and can be laid in wall without regard to its position in the quarry. It is of very fine texture and when newly quarried, quite soft, hardening on exposure; for carving purposes it has no superior. It is thoroughly saturated with oil which accounts for its discoloration and also makes it impervious to water; to stain it with Portland cement is an impossibility. The local cemetery contains monuments made of this stone which were erected over eighty years ago and still show no signs of deterioration. It was used on the St. Thomas Church, 53rd St. and 5th Ave., N. Y., Lothrop Residence and McLellan Statue, Washington, D. C., is being used in Philadelphia, Baltimore, Salt Lake City and many other places.

There are now seven quarries in operation, one of which has been running for more than forty years.

Underlying the three beds above described there is a ten foot bed of laminated oolitic limestone, which has a blue grey color, is very hard, almost, if not equally, as hard as granite, splits readily into thin sheets or beds and is used for street curbing and flagging; there are many miles of this curbing in Bowling Green and not an inch of it shows splits or weathering. Two churches have been built here of this hard stone which the writer had the pleasure of showing to Mr. Wenderoth some months ago; he was very favorably impressed with the hardness and handsome appearance of the stone, which, without doubt, would make a good substitute for the granite generally used below first floors on postoffice buildings.

This is not, by any means, intended as an advertisement of Bowling Green stone, but, to the superintendent who may never have had this product under his observation I will say, by way of conclusion, should you ever find

your contractor delivering a lot of dark, greasy looking stone at your building ascertain if it is Bowling Green stone and if it is don't lose any sleep about its color for it will eventually bleach to the prettiest light grey you ever saw.

JOHN LONGWORTH,
Supt. of Construction, Federal Bldg.,
Bowling Green, Ky.

KENTUCKY ROCK ASPHALT.

BY

MALCOLM H. CRUMP.*

Kentucky Rock asphalt is found principally along the southern and eastern outcrop of the western coal field of Kentucky. It has been opened and commercially developed in the counties of Edmonson, Warren, Logan, Breckinridge and Grayson. It is known to outcrop in Hancock and Hardin and is reported to be in Hopkins. It is also found to a limited extent in Northeastern Kentucky, notably near Soldier on the C. & O. R. R. in Carter county.

Geologically, it appears in the Chester sandstones and in the lower sandstones of the coal measures, including the Conglomerate sandstone. The rock is very generally a sandstone which has been, more or less, saturated with petroleum, the latter (which completely coats each face of every individual grain of sand and thus forms a cementing material) being oxidized and the lighter oils driven off by exposure to the air. It is in fact, an "oil sand" which has been brought to the surface and which after exposure to the elements, forms a mass which can be separated only by crushing and grinding. The percentage of bituminous matter contained varies from 5% to 21%, 7% is the amount required for commercial uses, this amount having been found best for its use as a practical road or surfacing material. The thickness of the beds runs from 3 to 30 feet, though it is reported as high as 40 feet in bored wells. It is usually worked on the outcrop, where the stripping of earth and shale or sandstone may run from nothing to a thickness equal to that of the asphalt bed. It is more or less irregular in thickness with a tendency to pockets of variable extent and thickness; the quality is also irregular to some extent, as is usually the case with natural products. It is quarried in open cut with steam or

*This report will be followed by one on the Asphalt Rock on Nolin River and Bear Creek which is now ready to go to press.

hand drills and blasted with the usual explosives, either powder or dynamite. Stripping is done at one of the quarries, with a steam shovel. Asphalt rock has been successfully worked in several places—such as Garfield, Breckinridge Co.—less successfully at Big Clifty, Grayson Co.; near Russellville, Logan Co., Young's Ferry, Warren Co., and about 2 miles above Lock No. 4, at Asphalt, Edmonson Co., several miles below Brownsville, the county seat of Edmonson. Here it is found at the base of the conglomerate and also in the Chester. The beds run from 5 feet to 15 feet in thickness. It is quarried in open cut after the stripping, which latter runs from one to ten feet in thickness and consists mainly of earth and sand, is removed by means of a steam shovel. This plant is owned and operated by the Wadsworth Stone and Paving Co., of Pittsburg, Pa., and is immediately on Green River, which has slack water navigation and is navigable every day in the year, and has as much as ten to twenty feet of water. The plant is readily accessible to the L. & N. R. R. at Bowling Green, Ky., and to the Illinois Central R. R. at Rockport, Ky., the first 50 miles away and the second 80 miles. The property consists of 300 acres in fee, and a still larger amount of mineral rights.

The boiler capacity of the plant is 275 H. P. The rock after being quarried, is broken to crusher size and carried on tram-cars a distance of one mile, to a jaw crusher, where it is reduced to the size of a walnut. It then passes through three pairs of rolls, about 18 inches in diameter and 24 inches long. It is here reduced as nearly as possible to individual grains of sand; every face, of every grain, is permanently coated with asphalt, and in this condition it is ready for use, as it is laid cold, without heating, or the admixture of any substance whatever. The above is a gravity plant from the quarry to the crusher, and thence to the barges on the river. The crusher is about 600 feet from the waters edge. To properly and ecomonically load the material on the barges, a solid concrete dock 8 feet thick at the bottom, and 11 feet above low water mark, has been constructed on piles driven 30 ft. into the river bed. On this dock there is a tipple 12 feet in height at the waters edge and running back to level ground 200 ft. from the river, where a per-

manent chute is fixed to receive the loaded dump cars from the plant, the material from which goes from either one or two tracks into this chute which delivers it to the barge. It is then towed to Bowling Green, where it is transferred by means of a clam shell elevator directly into the L. & N. cars, or into storage as occasion demands. The capacity of this plant is 300 tons in 24 hours.

MASTIC. In addition to the crushing, and grinding plant there are heaters and mixers for manufacturing Mastic. There are two heaters which are loaded, and discharged, four times in 24 hours, with a capacity of 50 tons for that time. This mastic is composed of about 75% of pulverized limestone, 20% of Ky. Rock Asphalt, and 5% of liquid asphalt, or bitumen. It is moulded into 50 lbs. blocks for convenience in shipping and hauling. The mastic is reheated at the place where used and properly seasoned to suit the needed requirements. It is used for water proofing floors of breweries, packing houses, ice houses, cold storage rooms, subways, and wherever a watertight and waterproof floor is needed. As stated above, the crude rock is found out cropping on the hills at least 150 ft. above the river and is a simple quarrying proposition, which usually carries an overburden of 5 to 15 ft., the rock asphalt being of about the same thickness. The overburden is removed by the use of steam drills and steam shovels after being first loosened by dynamite which effectually shatters the rock. The asphalt rock is also drilled with steam drills and shot with dynamite the same as any ordinary rock quarry. The material from this quarry has been and is being extensively shipped as far north as London, Canada, and west as far as Topeka, Kan., while large quantities go to New York for state highways, as well as to Pennsylvania, Cleveland and Columbus, Ohio, Detroit, Mich., and many other points.

SPECIFICATIONS.—The following specifications are for a roadway, having a 6 inch stone foundation and a 2½ inch wearing surface of Rock Asphalt, but they can be changed to suit local conditions and to comply with the engineer's standard requirements.

SUB-GRADE.—The sub-grade shall be brought to an even uniform surface parallel with the proposed finished surface. The entire sub-grade shall be rolled with a

steam roller of ten tons or more until it is thoroughly compact, and firm. Any portion not accessible to the roller shall be tamped.

FOUNDATION.—Upon this sub-grade thus prepared shall be spread clean, sharp hard limestone of the proper size and of such thickness that it will measure three inches after being thoroughly rolled. Upon this will be placed a three-inch layer of similar stone. After proper rolling this top layer shall be filled with limestone screenings or sand and also well rolled. The resulting surface shall present a true and even appearance 2½ inches below the proposed finished roadway and shall be sufficiently compact to sustain traffic without showing any depressions or ruts.

(Note).—Sandstone, trap, or furnace slag may be used in place of limestone, provided they are properly bound together with suitable material. A Telford base can also be used provided it gives a similar surface.

FINAL STONE LAYER.—On the foundation thus prepared there shall be spread a 2½ inch course of limestone. This course shall be given one rolling only. Just sufficient to smooth the surface to receive the asphalt.

ASPHALT WEARING SURFACE.—The roadway is now ready for the first layer of cold asphalt, which shall be dumped on working boards and not directly on the final stone course. Before spreading all lumps shall be broken or cut up so that it can be uniformly spread over the stone. It shall be spread with shovels, using about 20 lbs. per sq. yd. for the first layer. This layer is intended to partly fill the voids and hold the stone in place, while the second layer will fill the remainder of the voids, in addition to forming the wearing surface.

When sufficient area has been covered the asphalt shall be forced into the voids by rolling the area twice. After the first cover has been laid care should be taken to prevent any foreign matter being carried on this course before the second, or final course of asphalt has been spread. This is to insure the proper bond between the two courses. When a reasonable amount of the first layer has been completed the second, or final layer, shall be spread and raked to a uniform thickness of one inch in a loose state, using 60 lbs. to the sq. yd. The surface is now ready for the final rolling, but care must be taken

not to roll the surface too much immediately after laying. Two rollings are sufficient for the first day, after which it shall have one rolling each day for three successive days and the roadway shall be closed to traffic during that period. None of the completed first layer shall be left uncovered by the second layer over night. The rock asphalt used shall be equal to that quarried in the State of Kentucky, containing an average of 7% of natural bitumen and in no case shall the average be less than 6% and the material shall be ground as fine as possible, every grain separate and distinct being the ideal condition. Since it is of a sticky or viscous nature it cannot be screened, therefore a small percentage of coarse or lumpy material cannot be avoided; this is not particularly objectionable as during the rolling the lumps are either crushed or incorporated with surface material.

TEST FOR THE BITUMEN.—Five samples shall be taken from different parts of a given quantity (approximately one pound) which shall be thoroughly mixed and from which a test sample equal to 5 grains shall be taken and the bitumen removed by the ignition test. Carefully weigh the material before testing, and then the residue, which is silica sand. The difference represents the total amount of pure bitumen, which divided by five, will show the percentage of bitumen present. In selecting the test samples only finely ground material should be used.

QUANTITY REQUIRED.—The asphalt shall be spread in the two layers, so that one short ton (2,000 lbs.) will not cover more than 25 square yards of completed roadway.

PROPER TO LAY.—This should be done in warm, dry weather, but may be done in cool weather if clear and the temperature is not under 60°. F., and if additional time is allowed for the asphalt to settle and compact itself before opening the road to travel. If during the rolling of the final layer on a hot day, the asphalt sticks to the roller, the rolls should be greased with a thin coat of lubricating oil which will prevent further sticking. While a ten ton roller is necessary for the sub-grade and foundation, an eight ton tandem asphalt roller is preferable for rolling the asphalt surface, and it is further suggested that the speed of the roller be cut down one-half to prevent the asphalt surface from creeping in front of the roller. All the rolling connected with the entire con-

struction of a roadway, shall be started along the edges, and worked to the center or crown of the roadway. While it is natural for this material to cup and pick up in its early stages, after two weeks, or three at the most, this will cease, and produce a smooth, dustless, mudless and noiseless roadway, which is waterproof and practically automobile proof.''

SPECIFICATION FOR RESURFACING AN ORDINARY MACADAM ROADWAY.—''When possible, raise the crown of the road, clean the surface by removing all dust and loose material. The ruts and holes must be filled with stone, and the surface smoothed over, and thoroughly rolled. On this prepared surface there shall be spread a new top coat of limestone and asphalt in the manner specified under ''Final Stone Course,'' and ''Wearing Surface,'' which completes the roadway. When it is impossible to raise the grade or crown of the road to be resurfaced, all mud, dust and loose material shall first be removed and the surface of the old road shall then be loosened by using spikes in the steam roller, or by other practical means. The old wearing surface thus loosened shall be removed and the foundation shall be reshaped, so that the surface will be similar to that hereinbefore specified. ''For Foundation,'' thence proceeding as for a new roadway.''

A sample section of this material was put down in Bowling Green, Ky., August, 1907, by B. F. Heidel of the office of Public Roads, under the supervision of Vernon D. Pierce of the same department. Circular 89, Office of Public Roads, Department of Agriculture, Washington, D. C., April 20, 1908, says: ''As soon as one-half of the roadway had been surfaced and properly rolled, it was opened to traffic, in the hope that the asphalt would be further worked into the voids, of the stone by the action of the wheel and hoofs. At first the coating rutted badly, under the weight of the heavy loads of gravel and logs to which it was subjected, and the smoth surface given by the roller was seriously cut by the hoofs. This effect decreased visibly after three or four days. At the end of a week no trace remained of the deepest ruts, and the surface had become smooth and compact. It then presented an appearance not unlike that of an asphalt pavement, which has been opened for traffic for sometime. Practically little impression was made on the surface by

traffic after a week, except on very warm days, and this was not sufficient to impair its appearance or value. After four months the appearance of the roadway had undergone no appreciable change, but particles of limestone were exposed to view. This was undoubtedly due in large measure to the effect of forcing the asphalt into the voids of the stone, as a large part of the traffic is confined to the center of the pavement. The axis of the roadway had been more or less disturbed while the asphalt was being laid, and it is possible that the few protruding stones were those which had been raised above the general plane of the rock surface and were not covered to the same depth by the rock asphalt as the surrounding rock.

Incisions into the asphalt surface at this time revealed no perceptible loss by drying or hardening of the bitumen, as the sand particles showed their normal inclination to move when warmed in the hand. The permanence of macadam construction depends largely on the nature of the binder used, and the ability of traffic to supply by attrition the material removed by wind and water. It was to test the adaptability of rock asphalt as such a binding material, that the piece of construction was undertaken. The pavement is dustless, there is no appreciable wear of the surface material to be raised and carried away by the wind as dust, and such dirt as may be carried upon it is readily removed by sweeping or flushing with water. There is sufficient adhesive power in the bitumen to serve as a cement to hold the stone of the wearing surface in place—giving at once a smooth, and water-proof surface. It is resistent to deformation under a load, yet sufficiently plastic to break the severity of the blow from a horse's hoof, and thus in a measure avoid the harmful effects of a rigid pavement on animals. In 1910 another inspection showed the surface clean, smooth and compact, with no ruts, and having the appearance of a first-class asphalt city street. The individual crushed stones were tightly bound together, and not a single loose stone was found; the surface was everywhere hard and well compacted, and a small specimen of the rock asphalt, when dug out and

warmed in the hand showed that the surface bitumen still had considerable life.

To-day the surface presents a good appearance, firm and generally smooth, and the asphalt is apparently as alive as when first laid. Some of the white spots of limestone are still seen, but the individual stones are firmly held in place. There has been no raveling; some uneven places have appeared due to irregular scattering and spreading, together with slight defects in the foundation. It has passed the sixth winter and is found in excellent condition, though there have been no repairs. One of the recent U. S. Highway Inspectors when asked his opinion as to cost of maintenance, replied that one man with a motor car, and the crushed asphalt properly distributed along the road could maintain 25 miles indefinitely for ordinary traffic. The same material when used at Columbus, Ohio, showed, after several months of steady traffic, a surface as smooth as the best finished asphalt street, with no waves or cracks, and entirely free from dust. It is much like ordinary street asphalt and it is constructed without artificially heating the material, as well as without the admixture of any foreign substance; but just as it comes from nature. The experiment of the Federal Government at Bowling Green was made at the suggestion of the writer, and in his presence; hence he is prepared to substantiate everything stated.

It is very difficult to have the general public and the users of artificial asphalts understand that a natural material, or any other asphaltic substance can be laid cold and without mixing it with some liquid material such as oil, tar, or, artificially prepared asphalt. Substantiating this statement, B. F. Heidel, in a letter July, 1912, says:

"Speaking of Kentucky Asphalt which was laid on the Cemetery Pike at Bowling Green, Ky., Aug., 1907, this material was from the quarries of the Wadsworth Stone and Paving Co. on Green River, where it was prepared for use on the road by crushing. No other material, either sand or bitumen was added to change the consistency of the crushed, native product. The rock asphalt was applied to the wearing surface

of the stone at atmospheric temperature and at no time during the construction was artificial heat applied, either to the wearing course of stone, or to the rock asphalt.

Annual inspection has been made since that time by engineers from the Office of Public Roads in the Department of Agriculture. The reports show "that the pavement has remained practically unchanged in appearance, with little evidence of wear, and the bitumen has retained its life to the present time."

The same material is found in the Chester sandstone, north of Russellville, Ky., and in parts of Logan county in the same geological horizon, as that of Edmonson, Warren and Grayson. It is described by a mining engineer, as "a natural combination of asphalt or bitumen, with sand, and is of an unusual and remarkable nature. The asphalt is of the finest quality and the sand of a degree of hardness and sharpness unknown in this country or elsewhere, and is wonderfully adapted to street and road surfacing."

"It refines to 99% of its total bitumen at a cost not exceeding $5.00 a ton. For this high degree of purity, samples from both Edmonson and Logan counties yield 8 to 21% of bitumen and 92% to 79% of clean, hard white sand. The highest grades are too rich for road, and street work and must be reduced by mixing with a leaner material until a composition as follows, is reached: Asphalt 7% to 8%, Sand 93% to 92%, Quarrying is in open cut and is done by means of steam drills, and dynamite. Under some circumstances black powder is used to advantage. The bitumen or asphalt is equal to that found anywhere and the combination makes a high class durable surface for street and highways and is always laid without artificial heat or the use of limestone, or other material." At one quarry the average cost of quarrying and carrying to the crusher is 45 cents per ton, while the cost of crushing, grinding and putting on the cars is 80 cents. An opening on the Dismal Fork of Nolin in Edmonson county some ten miles West of Mammoth Cave is thus described by M. W. Venable, a distinguished civil and mining engineer of Charlestown, W. Va. "After an exhaustive examination,

the geological character of the country and locality seems to be regular, with no faults or displacements. The asphalt deposit lies about 90 feet below the top of the ridge and consists of a heavy stratum of very pure sandstone saturated with bitumen. The sand is held together entirely by the latter. When the impregnated sandstone is exposed to heat, the pitch, or bitumen collects on its surface. Therefore it may be expected that the out-crop indications only approximate the thickness, and richness of the stratum under the hill, yet the outcrop is from 15 feet upwards in thickness and rich enough to warrant its use on streets and road surfaces. The outcrop may be traced along the foot of the hill over the entire property and at every point its character remains constant. It is estimated that 9,000,000 tons of commercial material are found on an area of 350 acres. By a crude process of boiling 2240 lbs. of average rock asphalt, produced 80 gallons of crude bitumen, which was boiled down to 65 of refined material.

As a paint it appears to possess the consistency of refined caout-chouc. Spread on tin, no amount of bending or percussion breaks or cracks it. Exposed to the weather it neither cracks or peels. From its location and character, it can be mined very cheaply in opencut. This is the most valuable mineral property I have ever reported on.''

There are more than one hundred openings in Grayson and Edmonson counties, from Grayson Springs along, and on both sides of the divide between Bear Creek and Nolin river, where it is readily accessible to water transportation to the Ohio and thence throughout the Mississippi Valley. After a careful personal inspection, Dr. Edward Orton, late State Geologist, of Ohio, said:

''It may be stated that, while it is too much to expect that the first attempts to use a new material will be entirely successful and satisfactory, the results so far obtained are on the whole, sufficiently encouraging to warrant the prediction that Kentucky Rock Asphalt will be extensively used for street and highway surfacing. If the present methods of manipulation are not the best, better ones will be found. It took years of care-

ful experiments to bring the mixture known as Trinadad Asphalt to its present state of efficiency, and it will be strange if a material which exists in abundance so near the center of population of the U. S. (150 miles) and which comes from the hand of nature, so nearly what is required for a pavement (or surface) of the best class, shall not by a little skillful manipulation be perfected and made to supply this important demand."

The above prediction has been fully verified and substantiated by the numerous experiments and reports of U. S. Highway Engineers and contractors in many parts of the Union. Kentucky Rock Asphalt has passed the stage of experiment and is a recognized commercial product second to none for surfacing highways and streets. The fact that it can be used cold, without artificial cooking, or heating, and without the use of any outside material, such as liquid asphalt, oil or tar, and also without the use of pulverized limestone, greatly enhances its economic value. It has a very promising future, in this day of highway improvements, especially when it is considered that one short ton will surface one square rod about two inches deep, which amounts to 320 tons per mile for a roadway sixteen feet wide. At a cost of $5.00 per ton, this means $1,600.00 for an ideal boulevard which is practically waterproof, noise-proof, dust-proof, automobile-proof and well night indestructible. One man and a motor car can maintain indefinitely 25 miles, when the material is suitably distributed along the roadway.

A sample or specimen section has been laid on the Lincoln way at St. Helens, south of Louisville in Jefferson county, Kentucky, and it is the hope and expectation that the entire incoln-Jackson way from Louisville via the Lincoln Home at Hodgenville, thence by the Mammoth Cave and Bowling Green to Nashville, Tenn., a distance of 200 miles will be surfaced with this material. No roadway in the United States would equal this. As an automobile boulevard it could not be excelled. The Kentucky Rock Asphalt deposits parallel this highway for 120 miles and at no point are they more than 20 miles distant.

It is now being transported many hundred miles for streets and highways in far off states and Canada. It is a promising material and only needs such exploiting as an official report will give it.

It may well be considered the coming highway surface material for durable and economic construction. As before said the crushed and ground material, containing not less than 7% bitumen is used as a top dressing or surfacing material in the place of limestone or other screenings and produces a dustless, noiseless and inexpensive surface, which requires less work for construction than an ordinary water bound macadam. It is used raw, no artificial cooking or heating being necessary. The latter statement is repeated, because it is almost impossible to make the average highway contractor and some highway engineers understand that any asphalt, natural or artificial, can be used for surfacing without heating or cooking, by raising the temperature to 250 or more degrees. The only machine needed is the ordinary 10 ton steam roller, the asphalt being of such a nature that the rolling and later travel is amply sufficient to pack the roadway as smooth and hard as a regular pavement. The best results are obtained when the weather is warm on account of the fact that the asphalt is then in a better condition to pack. It should not be laid when the temperature is below 60° or while raining, but the warmer the day the better.

From this fact the material can be used in the far south all winter and in the far north during the heated summer months. A steam heated roller will permit it to be used everywhere at all seasons. The rock asphalt system of road construction is simpler and requires less labor than ordinary macadam, as less metal is needed and the hauling of several grades or sizes of stone is unnecessary, also one or two rollings are saved.

After the traffic is turned upon the road it beats down much harder and quicker than the water bound macadam and is never dusty, muddy or slippery. It approximates sanded rubber more nearly than anything else. The reason it is never dusty is that the asphalt, from its oily, viscous nature cannot form dust and quickly settles any outside dust that may fall upon it.

This asphalt surface will greatly outwear any macadam surface because the asphalt wearing surface does not grind up and blow away, and therefore remains a long time in good condition. It is well known that there are only two ways by which a stone or macadam road wears out, one by the action of water, the other by wind. The dust that forms from the grinding up of the stone is either washed away or blown away. Neither of these conditions can affect Rock Asphalt as it is both water-proof and dust-proof. Excellent samples of this material as a street surfacing material are seen at Bowling Green, Ky., on the public square, where it was laid in 1905, also at Birmingham, Ala., Belle Isle Park, Detroit, Mich., Sewickly, Pa., Emmett St., Evansville, Ind., (1907); Williamsville road, East Buffalo, N. Y. (1908); Euclid road, Cleveland, Ohio (1908); Nelson road, Ohio State Department, Columbus, Ohio (1909); U. S. Experimental road, Ithaca, N. Y. (1909); Seminary Ave., Greensburg, Pa. (1909); New York State road, No. 481, Pittsford road (1909); New York State road, No. 750, Clarence Center, N. Y. (1909); New York State road, No. 645, Orchard Park to Jewettsville (1909), New York State road, No. 642, Angola to Evans Center (1909); New York State road, No. 480, Churchville, N. Y. (1909); driveways, tennis court and athletic field, Belle Isle Park, Detroit, Mich. (1909); Staunton Military Academy, Staunton, Va. and many other places.

SOIL SURVEYS.

SOILS OF THE EASTERN COALFIELD.

BY

S. C. JONES.

The area embraced in the Eastern Coalfield that is generally referred to as the "Mountain Region of Kentucky" represents about one-fourth of the total area of the State or about 10,000 square miles. It has long been looked upon by those ignorant of its possibilities, as a practically valueless country. In truth it has been handicapped in the past, because or its poor wagon roads and absence of railroads, which meant that it was practically shut off from the rest of the world.

While this section of the State is not an agricultural country, the fact that its mining interests are being developed means also the development of conditions favorable for certain phases or types of agriculture.

GEOLOGY.

The coal measures of Eastern Kentucky are made up of shales, sandstones and conglomerates in the lower part of the formation, while the upper part is made up more largely of shales, clays, and sandstones.

The conglomerate or lower portion of the formation outcrops over a strip ranging from 5 to 25 miles wide, along the western border of the field. This area probably represents about one-third of the whole field and includes a portion of Wayne, Whitley, Pulaski, Laurel, Rockcastle, Jackson, Owsley, Lee, Estill, Wolf, Powell, Menifee, Morgan, Rowan, Elliott, Carter, and Greenup counties.

The rocks of the coal measures dip towards the southeast and the conglomerates that outcrop over the western margin of the field are carried under, leaving the upper coal measures outcropping over the remainder of the area.

TOPOGRAPHY.

The topography of this region is hilly and mountainous, the attitude varying from about 600 feet above sea level at the lowest points along the streams, to about 4,000 feet above sea level at the highest points in the Black Mountains near the Kentucky-Virginia State line. The height of the average hill is probably between 400 and 700 feet above the valley.

In the conglomerate area the hills are not so high and more or less ridge land is found, while as a rule in the remainder of the area the hills are high and steep and the ridges very narrow. Massive conglomerate and sandstone ledges outcrop in the hills in much of the conglomerate area, while sandstone ledges are much less numerous in the area formed from the upper coal measures.

The bottoms along the streams are as a rule narrow; however, there are exceptions to this rule.

SOILS.

Just as the geology of the conglomerate series differs from that of the upper coal measures so the soils formed from this series differ from those formed from the upper coal measures. The conglomerate soils are as a rule more sandy and in many places contain a heavy waste of conglomerate pebbles. They contain much less clay and consequently are much less retentative of moisture. As shown from the crop yields and their chemical analysis they have a much lower content of plant food than those formed from the upper coal measures.

The soils of the eastern coalfield may in a general way be divided into three divisions, viz.: Those of the ridges, those of the hillsides and those of the bottoms.

The ridge land is found mainly along the western border of the coalfield in the conglomerate area. Here the ridges contain soils varying from sand to sandy loams, silt loams or loams which are usually underlain with a more clay-like subsoil.

In the upper coal measures in Lawrence and Boyd counties are some very nice ridge lands containing

rather heavy soils. Here clay and shale predominate in the formation, which gives rise to apparently fertile loams or clay loams, on which blue grass and other grasses thrive very luxuriently.

On the hillsides in the eastern coalfield are found loams, silt loams, sandy loams and shale or gravel loams. The subsoils underlying these soils vary from a yellowish or reddish loam with more or less sandstone gravel intermingled.

The soils on hillsides facing east and north and those in the coves are usually deeper than those on the south and west hillsides. The south and west hillsides are regarded better for grass while the east and north hillsides are regarded better for cultivation.

It will be seen by observing the State geological map that streams are numerous in the eastern coalfield, along which are found more or less bottom land. The width of the bottoms varies, of course, with the size of the stream. Along many of the streams is found both a first and second bottom. The first bottom lies near the stream and is subject to overflow, while the second bottom is usually above the overflow line.

In the first bottoms brown sandy loams, and loams are found, while in the second bottoms are found silt loams, loams and clay loams of varying color, ranging from gray to yellow and brown. The gray soils are found in the wider bottoms near the base of the hill, and would be greatly benefited by artificial drainage. No doubt drainage would greatly benefit practically all of the second bottom soils.

SOILS OF ROCKCASTLE COUNTY.

GEOLOGY.

Rockcastle county lies just south of Madison and occupies a position somewhat intermediate between the counties of the "Blue Grass Region" and those of the mountain section of the State.

Being included mainly in the carboniferous formation it contains a series of geological horizons ranging from the coal measures down through the sub-carboniferous and into the Devonian and Silurian rocks.

From these formations are derived a number of soil types differing widely in their origin, topography, chemical and physical nature.

Rocks of the coal measures formation outcrop over the eastern portion of the county. At the base is found in places a massive conglomerate sandstone, while some 300 feet higher is another and similar conglomerate. Between these conglomerates the formation is made up of sandstone, sandy shales, coals and clays. The topography of this area is generally rough, the hills and cliffs rising rather abruptly to an altitude of from 200 to 500 feet inclosing very narrow valleys.

CHEMICAL ANALYSIS.

The following chemical analysis are by the Experiment Station chemists from average samples collected by the writer. They are calculated upon the sifted soil, after passing through a sieve with circular openings 2 m. m. in diameter. The per cent of gravel removed is stated after the chemical analysis.

CHEMICAL ANALYSIS OF ROCKCASTLE COUNTY SOILS.

Lower Coal Measures Soils, Calculated as Per Cent of the moisture-free Samples.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36237	36245	36238	36246
Total nitrogen	.1272	.0842	.0572	.0452
Total phosphoric acid	.0725	.0462	.0700	.0475
Phosphoric acid dissolved by n/5 nitric acid	.0018	.0008	.0009	.0003
Total potash	1.10	1.10	1.36	1.37
Lime dissolved by n/5 nitric acid	.1822	.1121	.0547	.0533
Potash dissolved by n/5 nitric acid	.0309	.0118	.0193	.0125
Acidity calculated as lime required to neutralize acid	.002	.002	.041	.104
Gravel removed by 2 m. m. sieve, as per cent. of air-dried sample	13.9	8.8	11.9	1.6

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36256	36261	36257	36262
Total nitrogen	.0740	.0610	.0360	.0205
Total phosphoric acid	.0663	.0575	.0675	.0650
Phosphoric acid dissolved by n/5 nitric acid	.0008	.0012	.0002	.0002
Total potash	1.03	.60	1.44	.72
Potash dissolved by n/5 nitric acid	.0176	.0090	.0117	.0113
Lime dissolved by n/5 nitric acid	.0631	.0617	.0294	.0280
Acidity, calculated as lime required to neutralize acid	.0065	.003	.1100	.025
Gravel removed by 2 m. m. sieve, as per cent of the air-dried sample	8.9	10.3	7.3	3.1

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36244	36265	36267	36268
Total nitrogen	.12332	.0430	.1960	.0370
Total phosphoric acid	.0725	.0563	.1413	.1113
Phosphoric acid dissolved by n/5 nitric acid	.0007	.0008	.0008	.0003
Total potash			1.34	1.89
Potash dissolved by n/5 nitric acid	.0128	.0084	.0224	.0134
Lime dissolved by n/5 nitric acid	.0336	.0308	.2397	.0841
Acidity calculated as lime required to neutralize acid	.002	.0115	.002	.021
Gravel removed by 2 m. m. sieve, as per cent. of the air-dried sample	9.0	.0	10.0	10.0

ST. LOUIS AND STE. GENEVIEVE SOILS.

Calculated as Per Cent of the Moisture-free Samples.

	Surface	Subsoil	Surface	Surface
Laboratory number	36239	36240	36241	36247
Total nitrogen	.1472	.0972	.1424	.1270
Total phosphoric acid	.1300	.0900	.0900	.0988
Phosphoric acid dissolved by n/5 nitric acid	.0009	.0005	.0010	.0026
Total potash	1.15	1.24		
Potash dissolved by n/5 nitric acid	.0139	.0117	.0213	.0116
Lime dissolved by n/5 nitric acid	.201	.2411	.1808	.1766
Acidity, calculated as lime required to neutralize acid	.003	.002	.0035	.0015
Gravel removed by 2 m. m. sieve as per cent. of the air-dried sample	4.9	7.3	1.3	1.3

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36249	36253	36250	36254
Total nitrogen	.1230	.0980	.0530	.0600
Total phosphoric acid	.1038	.0875	.0763	.0675
Phosphoric acid dissolved by n/5 nitric acid	.0012	.0010	.0004	.0005
Total potash	1.28	1.45	1.39	1.52
Potash dissolved by n/5 nitric acid	.0160	.0115	.0124	.0090
Lime dissolved by n/5 nitric acid	.1150	.2061	.0995	.1598
Acidity, calculated as lime required to neutralize acid	.0035	.0025	.004	.0605
Gravel removed by 2 m. m. sieve as per cent. of the air-dried sample	4.6	1.6	5.6	1.3

Waverly Soils.

Calculated as Per Cent of the Moisture-free Samples.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36242	36263	36243	36264
Total nitrogen	.0932	.0650	.0254	.0450
Total phosphoric acid	.0462	.0675	.0250	.0588
Phosphoric acid dissolved by n/5 nitric acid	.0020	.0009	.0004	.0007
Total potash	.67	2.04	.73	2.79
Potash dissolved by n/5 nitric acid	.0139	.0111	.0082	.0118
Lime dissolved by n/5 nitric acid	.0616	.0420	.0376	.0476
Acidity, calculated as lime required to neutralize acid	.005	.162	.036	.194
Gravel removed by 2 m. m. sieve as per cent of the air-dried sample	1.8	0.3	5.0	.0

	Waverly Soil Surface 0-6"		Chester Limestone Soil. Surface 0-6"
Laboratory number	36248	36251	36266
Total nitrogen	.0880	.0550	.1860
Total phosphoric acid	.0550	.0950	.1813
Phosphoric acid dissolved by n/5 nitric acid	.0017	.0018	.0006
Potash dissolved by n/5 nitric acid	.0132	.0169	.0243
Lime dissolved by n/5 nitric acid	.1458	.1317	.8187
Acidity, calculated as lime required to neutralize acid	.001	.030	.0005
Gravel removed by 2 m. m. sieve as per cent of the air-dried sample	4.3	17.1	.0

Bottom Soils.

Calculated as Per Cent. of the Moisture-free Samples.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36252	36258	36259	36260
Total nitrogen	.0990	.1680	.0890	.0150
Total phosphoric acid	.0538	.1375	.0838	.550
Phosphoric acid dissolved by n/5 nitric acid	.0010	.0007	.0007	.0003
Total potash			1.03	1.13
Potash dissolved by n/5 nitric acid	.0088	.0083	.0066	.0042
Lime dissolved by n/5 nitric acid	.0406	.3337	.0448	.0392
Acidity, calculated as lime required to neutralize acid	.0415	.002	.036	.076
Gravel removed by 2 m. m. sieve as per cent of the air-dried sample	0	2.2	1.3	0.8

From the tabulations given above it will be seen that the different samples of a soil area vary quite widely in their chemical nature.

Figuring that the surface soil (6 inches deep) over an acre weighs 1,900,000 pounds and that the succeeding 12 inches (6 to 18 inches deep) weighs 3,800,000 pounds, and expressing the results in terms of the element the following results are obtained from the Rockcastle county soils, using the averages of the analyses given.

Lower Coal Measures Soils.

	Total Nitrogen	Total Phosphorous	Available Phosphorous	Total Potassium	Available Potassium	Lime [CaO.]	Lime required to neutralize acid
Surface soil	1870	600	7.92	16,306	243	2249	78
Subsoil	1371	1181	5.1	42,768	429	1876	2287

St. Genevieve and St. Louis Soils.

	Total nitrogen	Total Phosphorous	Available Phosphorous	Total Potassium	Available Potassium	Lime [CaO.]	Lime required to Neutralize Acid
Surface soil	2384	823	11.03	19,423	234	3344	53
Subsoil	2662	1359	6.5	43,620	348	5829	843

Waverly Soils.

	Total Nitrogen	Total Phosphorus	Available Phosphorus	Total Potassium	Available Pottassium	Lime [CaO.]	Lime Required to Neutralize Acid
Surface soil	1431	538	12.97	21,368	219	1809	1254
Subsoil	1307	685	8.98	55,500	315	1619	4370

Bottom Soils.

	Total Nitrogen	Total Phosphorus	Available Phosphorus	Total Potassium	Available Potassium	Lime [CaO.]	Lime Required to Neutralize Acid
Surface soil	2259	749	6.5	16,243	126	2176	504
Subsoil	570	799	4.9	35,640	133	1489	2888

In the bottom soils only a single subsoil was analyzed which from some cause was exceedingly poor in nitrogen. Otherwise the Waverly soils are the poorest in both total nitrogen and total phosphorus but the richest in soluble phosphorus and total potassium. The subsoils are all strongly acid; also the surface of the Waverly soils.

Chemical Analyses of Perry County Soils.

Upper Coal Measures. Upland.

Calculated as Per Cent of the Moisture-free Samples.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36534	36536	36535	36537
Total nitrogen	.171	.145	.088	.054
Total phosphoric acid	.150	.1675	.0975	.0912
Phosphoric acid dissolved by n/5 nitric acid	.0066	.0157	.0025	.0057
Total potash	2.04		2.27	
Potash dissolved by n/5 nitric acid..	.0174	.0188	.0151	.0095
Lime dissolved by n/5 nitric acid....	.278	.084	.127	.0913
Acid calculated as lime required to neutralize	.002	.0035	.002	.001

	Surface 0-6"		Subsoil 6-18"	Surface 0-6"
Laboratory number	36538	36539	36540	36541
Total nitrogen	.326	.213	.090	.170
Total phosphoric acid	.1687	.1175	.080	.1275
Phosphoric acid dissolved by n/5 nitric acid	.0043	.0016	.0016	.0014
Total potash		2.31	2.67	2.70
Potash dissolved by n/5 nitric acid	.0290	.0267	.0135	.0180
Lime dissolved by n/5 nitric acid	.510	.258	.116	.300
Acid calculated as lime required to neutralize	.0035	.003	.012	.0015

	Surface 0-6"	Subsoil 0-18"
Laboratory number	36542	36543
Total nitrogen	.220	.123
Total phosphoric acid	.135	.115
Phosphoric acid dissolved by n/5 nitric acid	.0024	.0012
Total potash	2.75	2.29
Potash dissolved by n/5 nitric acid	.0332	.0215
Lime dissolved by n/5 nitric acid	.402	.244
Acid calculated as lime required to neutralize	.002	.0015

Perry County Soils—Bottom.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36544	36546	36545	36547
Total nitrogen	.120	.108	.092	.080
Total phosphoric acid	.135	.165	.1100	.105
Phosphoric acid dissolved by n/5 nitric acid	.0014	.0014	.0008	.0008
Total potash	2.38			
Potash dissolved by n/5 nitric acid	.0088	.0095	.095	.010
Lime dissolved by n/5 nitric acid	.130	.105	.126	.064
Acid calculated as lime required to neutralize	.004	.006	.004	.021

Johnson County Soils—Upland.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36248	36252	36249	36253
Total nitrogen	.091	.121	.046	.059
Total phosphoric acid	.0587	.0912	.050	.0575
Phosphoric acid dissolved by n/5 nitric acid	.0013	.0010	.0014	.0006
Total potash	2.00		2.65	
Potash dissolved by n/5 nitric acid	.0146	.0249	.0125	.0162
Lime dissolved by n/5 nitric acid	.095	.074	.073	.036
Acid calculated as lime required to neutralize	.004	.028	.061	.1675

Johnson and Magoffin Counties—Bottom.

	Johnson County.		Magoffin County.	
	Surface	Subsoil	Surface	Subsoil
Laboratory number	36250	36251	36254	36255
Total nitrogen	.092	.056	.136	.081
Total phosphoric acid	.1337	.1037	.105	.080
Phosphoric acid dissolved by n/5 nitric acid	.0027	.0012	.0013	.0004
Total potash	2.01	2.11		
Potash dissolved by n/5 nitric acid	.0189	.0132	.0168	.0130
Lime dissolved by n/5 nitric acid	.074	.055	.108	.108
Acid calculated as lime required to neutralize	.0135	.037	.007	.0095

Floyd County—Bottom.

	Surface	Subsoil	Surface	Subsoil
Laboratory number	36256	36257	36260	36261
Total nitrogen	.142	.102	.133	.067
Total phosphoric acid	.160	.1475	.215	.1637
Phosphoric acid dissolved by n/5 nitric acid	.001	.0004	.0015	.007
Total potash	3.03	2.86		
Potash dissolved by n/5 nitric acid	.0363	.0136	.0143	.0095
Lime dissolved by n/5 nitric acid	.119	.126	.165	.148
Acidity calculated as lime required to neutralize	.0195	.025	.004	.010

Floyd County—Upland.

	Surface.	Subsoil
Laboratory number	36258	36259
Total nitrogen	.138	.073
Total phosphoric acid	.1737	.1825
Phosphoric acid dissolved by n/5 nitric acid	.0034	.0018
Total potash		
Potash dissolved by n/5 nitric acid	.031	.0346
Lime dissolved by n/5 nitric acid	.193	.108
Acidity calculated as lime required to neutralize	.0015	.0055

Pounds of Plant Food Per Acre—Upper Coal Measures.

Upland Soils.

	Total Nitrogen	Total Phosphorous	Available Phosphorous	Total Potassium	Available Potassium	CaO.	Lime Required to Neutralise Acid
Surface	3369	1086	31.6	37,217	409	4532	106
Subsoil	3088	1561	55.	77,908	552	4306	1260

Pounds of Plant Food Per Acre—Upper Coal Measures.

Bottom Soils.

	Total Nitrogen	Total Phosphorous	Available Phosphorous	Total Potassium	Available Potassium	CaO.	Lime Required to Neutralise Acid
Surface	2294	1244	12.6	42,817	278	2058	171
Subsoil	3154	1906	23.8	73,679	800	3971	1216

It will be seen by observing the tabulations given above that the upper coal measures soils contain on an average, about twice as much total nitrogen, total phosphorus and total potassium, as the lower coal measures soils. Also that they contain a much larger amount of soluble phosphorus and potassium.

The fact that the bottom lands in the upper coal measures are so much poorer in total nitrogen and soluble phosphorus and soluble potassium is no doubt due to their long cultivation without any system of crop rotation. All of these soils are decidedly acid.

The future of the soils of the eastern coalfield lies in the development of forestry, horticulture, grazing, truck-gardening, and the production of poultry.

There are large areas of rough sandy land in parts of this region that are fit only for forestry. Such areas are usually found along the dividing ridges between the main waterways. Many of these areas have already fallen into the hands of companies that are handling the forest with more or less care, employing such methods

as will increase their productiveness, while as a rule the forest belonging to the individual is being rapidly destroyed.

It is perhaps safe to say that there is a greater future for horticulture in eastern Kentucky than for any other phase of agriculture. While it is true that the large fruits, such as apples, peaches, and pears are often damaged by late freezes and frost, yet if the proper varieties were grown and the orchards properly cared for no doubt damage could be materially decreased. Grapes and other small fruits appear to do especially well when given attention.

On the hillsides containing the loamy soils or soils of more claylike nature and even on the sandy soils such grasses as orchard grass, red top, English blue grass, and even Kentucky blue grass, thrive well when given favorable opportunities. The great reason for failure in growing grass is that the land is corned to death before an attempt is made to produce grass. When sown in new land that has been well cared for success usually results. Japanese clover grows wild and is now the chief grass for pasture.

Sheep will no doubt be the most profitable animal for this country, especially when more important breeds take the place of the mountain sheep.

With the increase in mining population the bottom lands will naturally be converted into truck gardens. Much of the bottom land has been cultivated in corn year after year for the last 75 or 100 years, and is badly worn, especially that lying above the overflow line. The overflow land is practically as fertile as when first cultivated.

SOIL SURVEY OF WEBSTER COUNTY.

BY

S. C. JONES

Webster County lies in the coal field of Western Kentucky, within parallels 37° 40′ and 37° 21′ north latitude, and Meridians 87° 23′ and 87° 56′ west longitude. Union and Henderson, two counties lying on the Ohio River, form its northern bounary. On the east, Green River separates Webster from McLean County, while Hopkins forms the southern, and Crittenden the western boundary. Its greatest length is about 33 miles and its greatest width 15 miles, with an area of approximately 335 square miles.

PHYSIOGRAPHY AND DRAINAGE.

The county represents three phases of topography: First, the low flat bottoms lying mainly between 350 and 400 feet above sea level; Second, the undulating or gently rolling upland lying between 360 and 440 feet above sea level, and third, the broken or hilly upland lying between 400 and 640 feet above sea level.

This broken area lies, in the main, in a broad range of hills eight or ten miles in width, extending from the county line on the south just west of Slaughterville, across the central portion of the county in a north-westerly direction, striking the Union County line some three miles southeast of the juncture of Union, Henderson and Webster counties. This escarpment forms the main water shed of the county, and lies about half way between Green and Tradewater rivers and divides the county into an eastern and western drainage area of about equal size.

Just west of this range of hills, extending across the county in a parallel direction, is a low undulating valley some five or six miles in width, made up of broad bottoms with low undulating upland lying between. This

valley was perhaps at one time the channel of Tradewater River or of a kindred stream which has long since shifted westward.

Still farther west, lying between this valley and the Tradewater River, extending in the same direction entirely across the county, is another range of disconnected hills interspersed with undulating areas and narrow bottoms.

On the east side of this escarpment is a narrow range of hills reaching out in a line from Dixon to Sebree almost to Green River. On the north, between this range of hills and the county line, is another strip of low, gently rolling land with wide bottoms along the streams. East of this area are the wide bottom lands of Green River and Deer Creek.

GEOLOGY.

Webster County lies entirely within the western coal field and its geology is characteristic of this field. Coals number 9 and 11 and probably, in places, still higher coals, outcrop at points over the more rugged area of the county. The formations consist of alternating strata of sandstone, sandy shales, clays, coals, slaty materials, and, at certain horizons, thin layers of limestone. Sand is the predominating material composing these formations and on disintegration rather uniform sandy or silty soils are formed.

SOILS.

Classifying the soils of the county as to origin, two kinds are recognized, viz: residual and transported. The residual soils occupy the upland and have been formed from the materials remaining in place after the disintegration of the overlying rocks, thus forming a cover over the deeper unaltered rocks, while the transported soils occupy the bottom lands and have been carried in by the waters of the small streams and rivers. Of the total area, 335 square miles, there are 123 square miles of land of transported origin and 212 square miles of residual origin.

SOIL TYPES.

Classifying the soils of Webster county according to their origin, topography and physical characteristics, such as their content of sand, silt, clay, organic matter, color, etc., five types are recognized. Three are in the area of transported origin and two in the upland or residual area. Naming in order of area, these five types are as follows:

Table I, Soil Types in Webster County.

	Sq. Mi.	Acres.	Per Cent.
Yellow Silt Loam (Hilly)	121.0	77,440.	36.1
Yellow Silt Loam (Undulating)	91.3	58,432.	27.3
Gray Silt Loam (Bottom)	84.8	54,272.	25.3
Gray Clay Loam (Bottom)	27.1	17,344.	8.1
Dark Brown Clay Loam (Bottom)	10.8	6,912.	3.2

YELLOW SILT LOAM (HILLY.)

This type occupies mainly the central portion of the county with also a number of minor areas in the eastern and western sections. It occupies the broken or dissected portion of the area and is derived from the alternating sandstones, sandy shales, sandy slates, clays, etc., whose constituents on disintegration intermix, giving rise to soils of rather uniform physical characteristics. In its origin it is very closely related to the yellow silt loam of the undulating area, the chief difference being that of topography, which, for agricultural purposes, separates the two types quite widely.

The hills of this area are usually rather steep and vary from 40 to 240 feet in height, averaging perhaps scarcely more than 100 feet. As a rule, the ridges are very narrow and irregular in trend.

The surface soil is a yellowish or grayish silt loam of varying depth, ranging from 6 to 10 inches. While the soil of these two upland areas is referred to as a silt loam, it is, in fact, practically on the margin between a silt loam and a fine sandy loam. It is mellow and open and, unless tramped when wet, seldom breaks into hard clods and is almost as easy to plow as a real sandy loam.

The subsoil is more claylike in its properties. At a depth of from 10 to 15 inches it has a brighter yellow color with gray streaks and, in places, iron stains, while at from 15 to 30 inches it usually becomes decidedly more plastic, due to the much larger proportion of clay. It is a well drained soil, but at the same time possesses very good water holding properties. The surface soil is of such character as to allow rain water to enter easily, which is stored up in the more compact subsoil within easy reach of growing plants. Through the porous surface soil much moisture is rapidly lost, whereas much of it could be retained if the organic content of the soil were increased.

Beech, maple, hickory, sassafras, persimmon, walnut and the different varieties of oak constitute the characteristic vegetation.

Corn, wheat, tobacco and hay are the principal crops grown on this type. The yield of corn varies from 15 to 30 bushels per acre, that of wheat from 10 to 15 bushels, and tobacco from 600 to 1,200 pounds. Hay is made from timothy, clover, red top, cow peas and wild grasses. In recent years, clover is practically a failure unless manure is applied to the soil. A large amount of hay is made in the fall from cow peas, which often contain a rank growth of wild grass.

Forty years ago the greater portion of this area was in timber and when first cleared, good crop yields were obtained, but the soil has been very badly handled and but little effort has been made toward preventing the soil from washing. The writer has not found an area in the State where land has been gullied more than in this area. The soil being loose and the topography hilly, conditions have been conducive to erosion. However, if the proper system of rotation and cultivation had been practiced, much of this land would not have gullied to such an extent.

Land for farming purposes is valued at from $5.00 to $20.00 per acre.

The following table contains a mechanical analysis of a typical sample of the surface and subsoil of this type.

Table II, Mechanical Analyses of the Yellow Silt Loam (Hilly). Calculated Moisture Free.

	Surface Soil (o-6")	Subsoil (6"-18")
Laboratory Number	36013	36014
Fine Gravel, 2 to 1mm	0%	.0%
Coarse Sand, 1 to .5 mm	0.4%	.0%
Medium Sand, .5 to .25 mm	0.3%	.2%
Fine Sand, .25 to .1 mm	0.9%	.3%
Very Fine Sand, .1 to .05 mm	4.7%	5.1%
Silt, .05 to .005 mm	80.3%	72.0%
Clay, .005 and under	12.6%	24.6%
Total	99.2%	102.2%

All passed through the 2 mm seive.

The mechanical analysis shows it to be decidedly a silty soil with practically twice as much clay in the subsoil as in the surface, while there is a larger per cent of silt in the surface. The sample of surface soil represents the first six inches and that of the subsoil the succeeding twelve inches.

The following table contains the results of the chemical analysis of the same samples, surface and subsoil.

Table III, Chemical Analyses of the Yellow Silt Loam (Hilly). Calculated Moisture-Free.

	Surface Soil	Subsoil
Laboratory Number	36013	36014
Total nitrogen	.056 %	.038
Total phosphoric acid	.0613%	.0863%
Phosphoric acid dissolved by n/5 Nitric Acid	.0024%	.0019%
Total potash	1,779%	1.989 %
Potash dissolved by n/5 Nitric Acid	.013 %	.0112%
Lime dissolved by same	.087 %	.061 %
Acidity calculated as lime required to neutralize	.005 %	.0945%

In the following discussions the phosphoric acid, potash and lime dissolved by one-fifth normal (n-5) nitric acid will be designated "available" because we think they may be taken as a measure of what is immediately available as plant food.

Over an acre to a depth of six inches, figuring from their apparent specific gravity, there are in the silt loams of this area approximately 1,900,000 pounds of soil. Figuring on this basis and expressing the amount of plant food in terms of the elements, this soil contains, in the first six inches on an acre, 1,064 pounds of total nitrogen, 509 pounds of total phosphorus and 28,055 pounds of total potassium, while, in the subsoil (6 inches to 18 inches, 3,800,000 pounds), there are 1,444 pounds of total nitrogen, 1,421 pounds of total phosphorus and 62,733 pounds of total potassium.

In the surface soil, the fifth normal nitric acid solution shows an availability of 3.9 per cent of the total phosphorus, or 19.9 pounds per acre and 0.73 per cent of the total potassium, or 205 pounds per acre, while in the subsoil it shows an availability of 2.2 per cent of the total phosphorus, or 31.6 pounds per acre and 0.56 per cent of the total potassium, or 353 pounds per acre.

This soil is poor in both total nitrogen and total phosphorus, but a fair proportion of the total phosphorus is soluble in fifth normal nitric acid, or "available." While it contains a large percentage of total potassium, only a small proportion of this is soluble in fifth normal nitric acid, or "available." Both the surface and subsoil are poor in lime (CaO), yet the surface soil is only slightly acid, requiring only 95 pounds of lime (CaO) to the acre to neutralize the acid, while the subsoil (3,800,000 pounds) requires 3,591 pounds, or about two tons.

YELLOW SILT LOAM (UNDULATING).

This type includes 58,432 acres or 27.3 per cent of the entire county. It is embraced mainly in two areas, one lying between the hilly area and the Henderson county line on the north, and the other southwest of this area. Other small outlying tracts are found through the hilly region.

This type is gently rolling and occupies the low upland areas, the gentle slopes and the broad ridges. In its origin it is very similar to the "hilly" region, though

the soil is much deeper ranging from 12 to 20 feet to native rock, while on the hills, native rock is sometimes found at from 3 to 5 feet; as a rule, however, from 5 to 10 feet.

The surface soil is a yellow or grayish silt loam varying in depth from 6 to 12 inches. It is a very loose, open soil and usually contains more organic matter than the soil on the hills. It usually lies rolling enough to afford fairly good natural drainage, although, in the more flat portions, the soil becomes quite gray in color, indicating, of course, the need of artificial drainage.

The subsoil is of about the same nature as that of the hills, being slightly more gray in color in the flat or level areas.

The native vegetation on this type of soil seems to differ somewhat from that of the hills. On the hills the oaks seem to predominate, while on the undulating soil maple and beech are found more abundantly.

Practically the same crops are grown on the soil of this type as on the hills, with, however, much better yields. Corn yields from 20 to 50 or 60 bushels per acre, wheat from 10 to 30 or 35 bushels and tobacco from 1,000 to 1,500 pounds.

The writer found in this area one farmer who produced in 1910, 33 bushels of wheat per acre on 35 acres, and harvested in the summer from the same field one ton of clover per acre, which had been sown in the spring of the same year. The soil had been fertilized and manured, which seems necessary in recent years, if clover is to be successfully grown on either of these types of soil. This undulating land sells at from $20.00 to $75.00 per acre, the price depending on the location, state of cultivation, etc. In spite of the fact that this land lies well, there are to be found fields that, through lack of care, have gullied quite badly.

Below are given the physical and chemical analyses of two samples of both surface and subsoil from this area. No. 36,018 is the subsoil of No. 36,017 and No. 36,026 of No. 36,025.

Table IV.—Mechanical Analyses of the Yellow Silt Loan (Undulating). Calculated Moisture Free.

	Surface Soil 0-6"	Surface Soil 0-6"	Subsoil 6-18"	Subsoil 6-18"
Laboratory number	36017	36025	36018	36026
Fine gravel, 2—1 mm.	2.1	1.4 %	1.5	1.0 %
Coarse sand, 1—.5 mm.	2.5	1.5	2.0	1.0
Medium sand, .5—.25 mm.	0.9	0.7	0.8	0.6
Fine sand, .25—.1 mm.	1.6	1.2	1.4	1.1
Very fine sand, .1—.05 mm.	6.2	3.9	5.2	3.7
Silt, .05—.005	76.5	82.8	72.3	67.8
Clay, .005 and under	8.9	9.5	17.1	22.4
Total	98.7	101.0	100.3	97.6

Sample 36,018 left a little sandstone gravel on the 2 m. m. sieve, amounting to 0.06% of the original. The other samples passed through entirely.

Table V.—Chemical Analyses of the Yellow Silt Loam (Undulating). Calculated Moisture-free.

	Surface 0-6"		Subsoil 6-18"	
Laboratory number	36017	36025	36018	36026
Total nitrogen	.074	.075	.033	.040
Total phosphoric acid	.0925	.0913	.0838	.0725
Phosphoric acid dissolved by n/5 nitric acid	.0027	.0011	.0022	.0006
Total potash	1.454	1.613	1.648	1.865
Potash dissolved by n/5 nitric acid	.0069	.0068	.0065	.0091
Lime dissolved by n/5 nitric acid	.084	.115	.073	.107
Acidity calculated as lime required to neutralize	.0065	.004	.108	.0955

These samples are typical of the area from which they were taken, and, as shown by the foregoing tables, are very similar in both their physical and chemical nature.

Figuring the average for the two samples on the acre basis (0 to 6 inches 1,900,000 pounds of soil) there are in the surface soil 1,416 pounds of total nitrogen, 763 pounds of total phosphorus and 24,184 pounds of total potassium, while in the subsoil (6 to 18 inches, 3,800,000 pounds) from the average of the two samples, there are 1,387 pounds of total nitrogen, 1,339 pounds of total phosphorus and 55,400 pounds of total potassium.

In the surface soil the fifth normal nitric acid solution shows an average availability of 2.07 per cent of the total phosphorus, or 15.8 pounds per acre, and 0.45 per cent of the total potassium, or 110 pounds per acre, while for the average of the two subsoils (6-18 inches, 3,800,000 pounds) it shows 1.7 per cent of the total phosphorus or 23.3 pounds per acre, and 0.44 per cent of the total potassium, or 246 pounds per acre.

This soil, also, is poor in total nitrogen and total and available phosphorus, and rich in total potassium but low in available potassium.

The content of lime and acid in this soil compares with that of the soil described above as the hilly phase of this type. To neutralize the acid in the surface, 1,900,000 pounds, requires 100 pounds of lime to the acre, while 3,867 pounds are required to neutralize the acid in the succeeding 12 inches (3,800,000.)

GRAY SILT LOAM (BOTTOM.)

In the western coal field there are hundreds of square miles of this low bottom land, 84.8 square miles of which are found in Webster county. This represents 54,272 acres or 25.3 per cent of the entire county. It lies mainly along the small streams and has been derived chiefly from the immediate upland. A good deal of this type is of recent origin, having been formed since the land was cleared and may be attributed largely to the hand of man in the increase of surface erosion due to cultivation of the uplands.

The surface soil is in the main a gray or yellowish silt loam, usually eight inches or more in depth, underlain by an incoherent silt of mealy texture. However, in the vicinity of the other types where back-water from the larger streams has played a part in soil formation, some variations have been introduced. Such areas are found on Stover Creek, Caney Fork and Deer Creek. Here the soil is underlain by a bluish or grayish clay loam, in places forming the surface soil. Generally, however, the surface is covered more or less with wash from the upland which gradually becomes deeper year by year.

With the exception of the narrow bottoms at the heads of the streams in the hilly area, the bottoms of

this type are rather broad and low and the great problem concerning their agricultural value is that of drainage. A large proportion of the area in these bottoms is wet and swampy, and except during dry seasons crops are drowned out. This land can largely be reclaimed by a well planned system of ditching and tiling. Some ditching has been done in the way of straightening and deepening streams, but so far, little tiling has been done.

Because of the high price of tile, the cost of laying and the doubt as to the value of drainage, the farmers are, as a rule, rather reluctant in attempting artificial drainage. These bottoms are timbered with a growth of black oak, red oak, sweet and black gum, sycamore and elm. The two varieties of gum are especially characteristic of the low wet areas.

Corn and hay are practically the only crops grown on this type. Tobacco is sometimes grown on the higher and better drained bottoms. Hay is made from timothy and from cow peas and wild grasses mixed. The average yield of corn and hay is low because of poor drainage. Land well drained will produce from 30 to 50 bushels of corn per acre, while the average yield is not more than 15 bushels per acre, and hay, of course, is likewise low in yield.

The value of land in these bottoms ranges from $10.00 to $50.00 per acre, the price varying with location, state of cultivation and drainage conditions.

Below are given the physical and chemical analyses of two samples of both surface and subsoils from this area. Sample 36,016 is the subsoil of 36,015 and 36,020 that of 36,019.

Table VI.—Mechanical Analyses of the Gray Silt Loam (Bottom). Calculated Moisture-free.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36015	36019	36016	36020
Fine gravel, 2—1 mm.	0.2	0.5 %	1.4	0.8 %
Coarse sand, 1—.5 mm.	0.7	0.6	0.6	.08
Medium sand, .5—.25 mm.	0.5	0.6	0.2	0.6
Fine sand, .25—.1 mm.	1.5	2.2	0.9	2.0
Very fine sand, .1—.05 mm.	8.3	13.4	5.5	18.6
Sile, .05—.005 mm.	82.1	70.0	80.2	68.2
Clay, .005 and under	8.2	11.5	11.8	9.6
Total	101.5	98.8	100.6	100.6

Sample No. 36,016 left a little sandstone gravel on the 2 m.m. sieve, amounting to 0.25 per cent. of the original. The other samples passed through entirely.

Table VII.—Chemical Analyses of the Gray Silt Loam (Bottom). Calculated Moisture-free.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36015	36019	36016	36020
Total nitrogen	.087	.086	.028	.057
Total phosphoric acid	.100	.090	.065	.080
Phosphoric acid dissolved by n/5 nitric acid	.0085	.004	.0025	.0039
Total potash	1.576	1.76	1.760	1.702
Potash dissolved by n/5 nitric acid	.0045	.0062	.0048	.0045
Lime dissolved by n/5 nitric acid	.105	.191	.097	.165
Acidity calculated as lime required to neutralize	.002	.001	.005	.005

This soil, like those of the upland types, contains a large per cent of silt, as shown by the mechanical analysis.

Figuring the average of the two samples on the acre basis (0 to 6 inches, 1,900,000 pounds of soil) there are in the surface soil 1,644 pounds of total nitrogen, 789 of total phosphoric acid and 26,304 pounds of total potassium, while in the subsoil (6 to 18 inches, 3,800,000 pounds) for the average of the two samples, there are 1,615 pounds of total nitrogen, 1,204 pounds of total phosphorus and 54,596 pounds of total potassium.

In the surface soil the fifth normal nitric acid solution shows an average availability of 6.6 per cent of the total phosphorus, or 51.9 pounds per acre and 0.32 per cent of the total potassium or 84.4 pounds per acre, while for the average of the two subsoils (6 to 18 inches, 3,-800,000 pounds) it shows 4.4 per cent of the total phosphorus or 53.1 pounds per acre and 0.27 per cent of the total potassium or 147 pounds per acre. This soil is much richer in available phosphorus and much poorer in available potassium than the soils of the upland. It is also decidedly richer in lime and is not as strongly acid. The surface six inches requires only 28.5 pounds of lime to neutralize the acid in an acre, while the succeeding twelve inches requires 190 pounds.

Gray Clay Loam (Bottom.)

In the area included in this type there are 27.1 square miles or 17,344 acres or 8.1 per cent of the entire county.

Taken as a whole, the soil is the poorest of any of the types recognized in the county, and the most variable in its physical characteristics. It is found in the bottoms in the eastern portion of the county along Green River and Deer Creek and in the western portion in the bottoms along Tradewater River and Craborchard Creek.

It differs in origin from the bottom (Gray Silt Loam) lying along the small streams in that the materials composing the soil have been largely transported from the Chester, St. Louis, and Waverly areas by the Green and Tradewater Rivers.

The topography of this type is much more broken, especially near the streams, than either of the other bottom soils, having in some places undergone considerable erosion.

The natural drainage of much of this area is fairly good, but away from the streams the more level parts would be greatly benefitted by artificial drainage. A great deal of the land along Tradewater River, Craborchard Creek and Deer Creek is overflowed during high water, while a large proportion lying along Green River is seldom overflowed.

Although other phases of soil are included, the larger portion as outlined in the area may be classed as a gray clay loam, locally known as "post oak." The surface is a gray loam underlain with a waxy clay subsoil usually of a bluish gray or yellow mottled color. Over much of the flat land, three or four inches of silty material is often found covering the surface and in places along Green and Tradewater Rivers are found patches of loam soils.

The growth of timber on this soil is usually scrubby and consists of post oak, red oak and hickory. Corn and hay are practically the only crops grown and the yields are very low, that for corn averaging from 12 to 15 bushels and hay about ½ ton per acre.

Only a small per cent. of the land is under cultivation and is valued very low. Sample 36,028 is the subsoil of 36,027 and 36.030 that of 36,029.

Table VIII.—Mechanical Analyses of the Gray Clay Loam (Bottom). Calculated Moisture-free.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36027	36029	36028	36030
Fine gravel, 2—1 mm.	2.8	2.6	2.2	0.0
Coarse sand, 1—.5 mm.	5.2	2.4	3.0	0.8
Medium sand, .5—.25 mm.	2.6	1.6	2.0	0.6
Fine sand, .25—.1 mm.	6.4	3.0	3.8	0.8
Very fine sand, .1—.05 mm.	7.1	7.5	4.4	4.8
Silt, .05—.005 mm.	53.1	47.1	51.5	38.0
Clay, .005 and under	22.3	34.7	32.0	54.2
Total	99.5	98.9	98.9	99.2

Samples 36,027 and 36,028 left a little sandstone gravel on the 2mm. sieve, amounting to 0.10% and 0.16% of the original, respectively. The other two samples passed through entirely.

Table IX.—Chemical Analyses of the Gray Clay Loam (Bottom). Calculated Moisture-free.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36027	36029	36028	36030
Total nitrogen	.099	.103	.054	.070
Total phosphoric acid	.1775	.0988	.1288	.0838
Phosphoric acid dissolved by n/5 nitric acid	.0018	.0010	.0010	.0027
Total potash	1.973	2.365	2.221	2.752
Potash dissolved by n/5 nitric acid	.0082	.014	.0076	.0182
Lime dissolved by n/5 nitric acid	.098	.095	.038	.114
Acidity calculated as lime required to neutralize	.096	.2135	.295	.426

The two samples representing this type differ considerably in physical characteristics. The one containing the largest percentage of silt and the smallest percentage of clay was taken from near the border of the area and has been somewhat modified by an intermixture of material from the neighboring type.

As determined by the apparent specific gravity, the soil of this type weighs to the acre, six inches deep, 1,800,000 pounds, while the succeeding twelve inches weighs approximately 3,700,000 pounds.

Figuring on this basis, and using the mean of the two analyses, the surface soil (0-6 inches, 1,800,000 pounds) contains 1818 pounds of total nitrogen, 1,087 pounds of total phosphorus and 32,405 pounds of total potassium to the acre, while the sub-soil (6-18 inches) contains 2,294 pounds of total nitrogen, 1,718 pounds of total phosphorus and 76,360 pounds of total potassium.

In the surface soil the fifth normal nitric acid solution shows an average availability of only 1.01 per cent of the total phosphorus or 11.1 pounds per acre, and 0.51 per cent of the total potassium or 166 pounds per acre, while for the sub-soil (6-18 inches) it shows 1.74 per cent of the total phosphorus or 29.9 pounds per acre, and 0.52 per cent of the total potassium or 396 pounds per acre.

Although this soil is comparatively rich in total plant food, it is generally recognized as a poor unproductive soil, which is perhaps due to the low content of available plant food, especially low available phosphorus, as well as to its high acidity, it being low in lime and strongly acid. According to the acidity determination, the surface soil requires 2,786 pounds of lime per acre and the sub-soil (6-18 inches) 13,339 pounds of lime to neutralize the acid.

DARK BROWN CLAY LOAM (BOTTOM).

Of this type there are 10.8 square miles or only 3.2 per cent of the whole county. It represents the most fertile land in the county and is found in practically the same localities as the Gray Clay Loam. It is of a similar origin, but appears to be more recent since it has a higher altitude and is underlain by a material resembling very much the Gray Clay Loam. It may have covered much of the territory now occupied by the Gray Clay Loam, but has long since been eroded.

This soil is a dark brown clay loam rather impervious and difficult to work when poorly drained. It bakes hard in the sun and when plowed wet forms com-

pact clods which crumble and fall to pieces like quick lime when rain falls on them. The sub-soil is usually plastic and has a dark blue gray color. The dark color of this soil is due to an accumulation of vegetable matter. Only the areas near the upland along the small streams are subject to overflow, but the land lies level and is not fit for cultivation until drained. Twenty years ago this land was looked upon as being worthless, but recently much of it has been cleared and brought under cultivation. In the area in the eastern portion of the county in the Green River bottom, are now to be found farms valued at $50.00 and $60.00 per acre. In this tract much land has been drained. The native forest growth consists of sweet gum, oak and hickory.

Corn, wheat and hay are grown on this soil and occasionally tobacco, which, however, is usually of a very poor quality. Corn yields from 60 to 75 bushels, wheat from 20 to 30 bushels and hay two tons per acre on land tile drained. Hay is made from clover and timothy. The soil seems especially adapted to the growth of both.

Table X.—Mechanical Analyses of the Dark Brown Clay Loam (Bottom). Calculated Moisture-free.

	Surface Soil 0-6″	Subsoil 6-18″
Laboratory number	36023	36024
Fine gravel, 2—1 mm.	0.8 %	1.4 %
Coarse sand, 1—.5 mm.	2.2	6.2
Medium sand, .5—.25 mm.	2.6	5.2
Fine sand, .25—.1 mm.	9.2	9.8
Very fine sand, .1—.05 mm.	13.4	5.7
Silt, .05—.005 mm.	46.7	48.5
Clay, .005 and under	21.1	20.2
Total	96.0	97.0

The 2 mm. sieve removed from samples 36,023 and 36,024 some gravel consisting mainly of rounded sandstone fragments and quartz pebbles and amounting to 0.44% and 3.80% of the original, respectively. Samples 36,021 and 36,022 passed through entirely.

Table XI.—Chemical Analyses of the Dark Brown Clay Loam. (Bottom). Calculated Moisture-free.

	Surface Soil 0-6"		Subsoil 6-18"	
Laboratory number	36023	36021	36024	36022
Total nitrogen	.163	.226	.118	.163
Total phosphoric acid	.0963	.1200	.075	.1163
Phosphoric acid dissolved by n/5 nitric acid	.0084	.0061	.0059	.0057
Total potash	2.144	2.737	2.221	2.748
Potash dissolved by n/5 nitric acid	.0133	.0278	.0127	.0199
Lime dissolved by n/5 nitric acid	.431	.526	.417	.501
Acidity calculated as lime required to neutralize	.002	.001	.0025	002

Sample 36,022 is the subsoil of 36,021 and 36,024 that of 36,023.

The chemical analysis, in harmony with the crop yields, indicates in this instance a fertile soil. In fact, this is decidedly the most fertile soil in Webster county.

As determined by the apparent specific gravity, the surface soil to a depth of six inches over an acre weighs approximately 1,750,000 pounds while the succeeding twelve inches weighs approximately 3,600.00 pounds.

Figuring on this basis, from the average of the two analyses, the soil on an acre, to the depth of six inches, contains 3,403 pounds of total nitrogen, 827 pounds of total phosphorus and 36,174 pounds of total potassium, while the subsoil (6-18 inches) contains 5,058 pounds of total nitrogen, 1,505 pounds of total phosphorus and 74,237 pounds of total potassium.

In the surface soil the fifth normal nitric acid solution shows an average availability of 6.7 per cent of total phosphorus or 55.4 pounds per acre and 0.82 per cent of the total potassium or 298 pounds per acre, while in the average of the subsoils (6-18 inches) it shows 6 per cent of the total phosphorous or 91 pounds per acre and 0.66 per cent of the total potassium or 487 pounds per acre.

This soil is fairly rich in both total and available plant food and is also quite rich in lime, and according to the acid test, only 26 pounds of lime is required to neueralize the surface (0-6 inches) and 81 pounds to neutralize the subsoil (6-18 inches).

The weights of soil to the acre, calculated from the apparent specific gravity, are: For the Dark Brown Clay Loam, first 6 inches, 1,750,000 pounds to the acre, and the next 12 inches, 3,600,000 pounds to the acre; for the three silt loams, first 6 inches, 1,900,000 pounds, the next 12 inches, 3,800,000 pounds; for the Gray Clay Loam, first 6 inches, 1,800,000 pounds, and the next 12 inches, 3,700,000 pounds.

Table XII.—Plant Food in the Surface Soils (0 to 6 inches). Calculated in Pounds to the Acre.

	Total Nitrogen	Total Phosphorus	Phosphorus dissolved by N-5 Nitric Acid	Total Potassium	Potassium dissolved by N-5 Nitric Acid	Lime dissolved by N-5 Nitric Acid	Lime required to neutralize the acidity
Dark Brown Clay Loam (bottom)	3303.	826.	55.	35,441.	298.	5365.	26.
Gray Silt Loam (bottom)	1644.	789.	52.	26,304.	84.	3912.	29.
Yellow Silk Loam (undulating)	1416.	763.	16.	24,184.	110.	1891.	100.
Loam (bottom)	1644.	789.	52.	26,304.	84.	3912.	29.
Yellow Silt Loam (Hilly)	1064.	509.	20.	28,055.	205.	1653.	95.
Gray Clay Loam (bottom)	1818.	1087.	11.	32,405.	166.	1737.	2786.
Average of 4 types omitting the Dark Brown Clay Loam	1486.	787.	25.	27,737.	141.	2298.	

AGRICULTURAL CONDITIONS.

The land of Webster county is assessed at $1,844,685 or 48 per cent of the total taxable property, which is $3,843,550. Figuring on this basis, land is assessed at an average of $8.64 per acre, which is in all probability not far from one-half of the real value.

In many counties in the state, land constitutes more than one-half of the total wealth, but in Webster county at present, mining interests predominate.

Formerly there was much large timber which, had it been preserved, would today be worth far more than

the land, but because of a lack of thought and foresight it has been wasted until at present but little remains. In the upland there is practically none, while some small tracts are yet to be found in the bottoms.

Webster is at present, and has long been, a great tobacco producing county. Hopkins, Union, Henderson, Crittenden and Webster counties produce a dark tobacco, which is fire cured. These five counties produce annually an average of about twenty-five million pounds. For the last few years they have been selling together, and received in 1908, 8 cents and 1909, 7 cents per pound, the difference in price being due to a difference in quality.

In Webster county practically all of the tobacco is grown in the two upland soil types. Through the use of the poor methods that have been practiced in handling these soils, tobacco culture is largely responsible for their depleted and worn condition. The growing of tobacco might have been made a profitable industry, and at the same time the fertility of the soil might have been maintained, had conservative methods of cultivation, fertilization and rotation of crops been employed.

It has been a custom to clear land and cultivate continuously for a few years until no longer profitable yields are obtained and then, to hold up the yields, the use of low grade commercial fertilizers has been resorted to, which has, in fact, served to rob the soil more rapidly of its fertility. After reaching this state, the land has often been thrown out without being sown in grass, and new fields have been cleared and this process repeated. Even when grass was sown, it has been difficult to get a growth and the soil of the cleared uplands has, consequently, suffered greatly from washing. This improvident kind of farming has been practiced until new land is no longer to be had. Many of the farmers who have participated in this wastefulness have lived to face the punishment of their sins. They have not only committed a crime against themselves, but against future generations as well. If, with new and fertile soils, they could not live and preserve the fertility of their lands, how now with worn and infertile soils are their sons to live and at the same time reclaim these worn lands? The solution of the problem depends upon the farmers them-

selves. The effort here is to present such information as will enable them to reach the solution. The conditions referred to above are especially true of the hilly type. However, they are true to some extent of the undulating soils.

Through practicing a well planned system of diversified farming, these worn lands may eventually be made profitable. The uplands are especially adapted to fruit growing and particularly peaches and apples, which are not now profitable because the proper attention is not given to their care. The rougher portions should be planted in trees of a quick growth, such as locust, which in twenty years will begin to yield profits. The cultivated areas should remain in grass at least three-fourths of the time and more attention should be given to grazing.

At present, Japanese clover constitutes the chief grass for pasturage. It is a very valuable plant, both for grazing and for storing nitrogen in the soil, but it is inadequate for the former purpose, because it does not appear until late in the spring, disappears with the first frost in the fall and will not stand drouth. There are many kinds of valuable grasses which thrive under varying soil conditions, and some, no doubt, exist which, if introduced, would completely revolutionize stock raising in the western coal field. Professor Garman of the Experiment Station, who has charge of the experimental work on grasses, suggests sheep fescue, orchard grass, red top and alsike clover for the upland silty soils.

According to the 1910 report of the Assessor of Webster county, there is, including all kinds of stock (horses, cattle, sheep and hogs) an average of one animal for every 14 acres of land, or less than seven head of stock for each one hundred acres in the county. While information from this source is not absolutely reliable, it no doubt represents fairly well existing conditions. Such a system of live stock farming is entirely too limited to be profitable, even on land as cheap as this.

When the proper attention is given to growing grasses, the rotating of crops with a judicious purchase and use of plant food on these soils, and when the bottom lands are reclaimed by artificial drainage, four

times as much stock may be kept and agriculture may be made a profitable industry for Webster county.

Both the crop yields and the chemical analyses indicate a lack of plant food in all these soils, with the exception of the Dark Brown Clay Loam. Even in this, the per cent of phosphorus is less than is desirable, but according to both the crop yields and its chemical nature, it would be classed as a fertile soil.

By comparing the chemical analyses of the five types of soil in the tabulation given below, a number of interesting relations may be brought out. The analyses have been arranged in the order of lime requirement, as determined by the acidity test, beginning with the lowest.

Table XII.—Plant Food in the Subsoils (6-18 Inches). Calculated in Pounds to the Acre.

	Total Nitrogen	Total Phosphorus	Phosphorus dissolved by N-5 Nitric Acid	Total Potassium	Potash dissolved by N-5 Nitric Acid	Lime dissolved by N-5 Nitric Acid	Lime required to neutralize acidity.
Dark Brown Clay Loam (bottom)	5040.	1488.	91.	73,502.	472.	16,524.	81.
Gray Silt Loam (bottom)	1615.	1204.	53.	54,596.	147.	4,978.	190.
Yellow Silt Loam (hilly)	1444.	1421.	32.	62,733.	353.	2,318.	3591.
Yellow Silt Loam (undulating)	1387.	1339.	23.	55,400.	246.	3,420.	3867.
Gray Clay Loam (bottom)	2294.	1718.	30.	76,360.	396.	2,812.	13339.

One very striking fact is that the amount of phosphorus soluble in the fifth normal nitric acid solution, assumed to be available, decreases as the acidity (lime required to neutralize the acidity) increases, with only one exception. This relation, however, does not hold in respect to the potassium. Roughly speaking, the soils showing most lime are least acid.

By considering the approximate amounts of plant food removed in farm produce, as given in the table below, the significance of these analyses may be more easily understood.

Table XIII.—Plant Food Removed in Farm Crops.

Crops.		Pounds of Plant Food.		
KIND.	Amount per acre.	Nitrogen.	Phosphorus	Potassium.
Corn, grain	50 bu.	50.	8.5	9.5
Corn, stover	1½ tons	24.	3.0	26.0
Corn, whole crop		74.	11.5	35.5
Wheat, grain	25 bu.	35.5	6.0	6.5
Wheat, straw	1¾ tons	12.5	2.0	17.5
Wheat, whole crop		48.0	8.0	24.0
Clover	2 tons	80.0	10.0	60.0

It will be seen that the total amount of potassium in these soils is far greater, in proportion to the amounts removed in corn, wheat and clover, than are the total amounts of either phosphorus or nitrogen, in proportion to the amounts of the substances removed in the same crops. Omitting the Dark Brown Clay Loam, and taking the average of the figures for nitrogen, phosphorus and potassium in the surface soil of the four poorer types, we have 1486 pounds of nitrogen, 787 pounds of phosphorus and 27,737 pounds of potassium to the acre in the first six inches of this average soil. Dividing these figures, respectively, by the weights of nitrogen, phosphorus and potassium in a 50 bushel crop of corn, (74, 11.5 and 35.5 lbs.) we find that this supposed average soil contains to the acre, in the first 6 inches, 20 times as much nitrogen, 68 times as much phosphorus, and 78 times as much potassium as there is in a 50 bushel corn crop. Hence, measured by the requirements of such a crop, the total supply of potassium is 11 times as great as the total supply of phosphorus and 39 times as great as that of nitrogen.

This would seem to indicate that nitrogen is the limiting element of fertility in these soils, which is perhaps true, especially on the upland soils where grain crops are grown, while where legumes are grown phosphorus would be the limiting element. It must be remembered, however, that the reserve supplies of nitrogen, phosphorus and potassium in soils do not become

available with equal rapidity and this circumstance may have great influence on the result.

In studying the chemical nature of soils, not only the total amount of plant food, but its availability, also, should be considered. This is one of the questions relating to soil fertility that is being studied at the Experiment Station. By available plant food is meant that which is in a condition to be utilized by growing plants. As a rule, only a small proportion of the total plant food in a soil is in an available form.

The chemists of the Kentucky Experiment Station employ a "fifth-normal" nitric acid solution to extract from a soil the available phosphorus and potassium. This is a very weak acid solution and is supposed to take up just about the amount that is in a form to be utilized by growing plants. Of course, the acid coming in contact with all the soil grains may remove from a soil a much larger proportion of plant food than a plant could and such a test is arbitrary, and may not be an absolute measure of the available plant food, but its results seem to have considerable relative value.

By considering amounts of phosphorus and potassium dissolved by N-5 nitric acid in the five types given in Table XII. above, it will be seen that the Dark Brown Clay Loam is the only soil that is rich in both available phosphorus and available potassium, and it has already been stated that it is by far the most fertile, as indicated by crop yields. It is also about twice as rich in total nitrogen, as the richest of the other four soils, and about three times as rich in lime.

Figuring the average for the other four types, there is practically twice as much available potassium in proportion to the amount of potassium removed by a 50 bushel crop as there is available phosphorus in proportion to the amount of phosphorus removed by such a crop. These relations are much closer than in some of the limestone soils of the State, where even the total supply of potassium is only about two-thirds the amount found in these soils.

According to the facts brought out by the chemical study of these soils, unbalanced conditions in regard to plant food seem to exist. If maximum crop yields are to be obtained and at the same time the soils remain fer-

tile, their nitrogen and phosphorus content must be increased and a larger per cent of their great store of inert potassium made available.

In Webster county, thousands of dollars are expended annually for the low-grade commercial fertilizers carrying only a small quantity of all three of these elements, especially nitrogen and potassium, when, as the evidence at hand indicates, really only phosphorus should be purchased. Because of the high price of commercial nitrogen, the farmer cannot afford to buy it for general farm crops. It can be added to the soil much more cheaply from the large store in the atmosphere by growing clover and other legumes, and at the same time accumulate organic matter, which will aid in rendering available the inert phosphorus and potassium of the soil. The legumes may be turned under directly or fed as hay and the manure returned to the soil, the latter method being regarded the more profitable. Then, assuming that potassium may be made available, only phosphorus remains to be purchased. The phosphorus may be purchased in the form of acid phosphate, bone meal or finely ground rock phosphate. The ground rock phosphate is much the cheapest form and will, no doubt, be practically as profitable with the proper system of crop rotation employed.

While the first 6 inches of only one of these soils is strongly acid, the application of lime would, in all probability, greatly improve them all, except the Dark Brown Clay Loam, for the growth of leguminous crops. In all these soils, except this, the subsoil is decidedly acid.

Limestone is scarce in the western coal field, but all around its border occurs an abundance of very pure limestone, which will furnish fine material for correcting acid soils when finely ground. There would, no doubt, be a market for such material, if it were only being produced.

Of the three types of bottom soil, there are all together about 78,500 acres, or 36.6 per cent of the whole county. Of this amount, the larger proportion is practically worthless until reclaimed by artificial drainage, which will, no doubt, increase the yielding capacity tenfold. So far, the farmer has been slow to take to the drainage proposition, because of the cost involved. As

a rule, he is not ready to look ahead, but must see an immediate income for the money expended before he is willing to invest.

At present, the cost of drainage is decidedly more than it should be because of the great distance tile must be transported. There is, no doubt, an abundance of clay in the county suitable for the production of tiling which, if worked by a plant of small capacity, would in all probability be a profitable industry for the operator and at the same time a big saving for the farmer.

Results of the Pot Culture Experiments.

While the soil with which the following results were obtained is not a Webster county soil, it is in every respect typical of the western coal field and has practically the same origin as those of the upland types in Webster.

It was collected from near Bremen, Muhlenberg county, in the fall of 1909, and may be correlated with the yellow slit loam (undulating) soil area of Webster county. Only the surface soil was taken, to the depth of 6 inches.

Its chemical nature, as determined by analysis, is very similar to that of the Webster county soil. It will be noted, however, that the amount of available potassium is about twice as large as in those from Webster county. Figuring on the same basis and expressing the plant food content in terms of the elements, this soil contains to the acre, in the first 6 inches, 1,577 pounds of total nitrogen, 623 pounds of total phosphorus and 25,705 pounds of total potassium. The fifth normal nitric acid solution showed an availability of 1.86 per cent of the total phosphorus, or 11.6 pounds per acre, and 1.6 per cent of the total potassium, or 411 pounds per acre. The acidity test showed 47.5 pounds of lime required to neutralize.

In the fall of 1909, three series of pot culture experiments were begun with this soil, in the Experiment Station Greenhouse. Series No. I. was planted in tobacco; series No. II. in clover, and series No. III. in wheat. After harvesting the crops, the soil in the pots was allowed to become dry during the summer. In the fall

of 1910, the soil of each pot was emptied out, worked over and the same kind and amount of fertilizer mixed with it as before, after which it was returned to its proper pot, moistened and the seed planted. Series No. I. was planted in oats; series No. II. in tobacco, and series No. III. in clover.

Series Nos. I. and III. were in 4-gallon jars, while series No. II. was in 2-gallon jars. Into each 4-gallon jar, 15,000 grams, or about 30 pounds of soil, were put, and one-half that amount into each 2-gallon jar.

Whether used alone or in combination, the following amounts and kinds of plant food were thoroughly mixed with the soil of the 4-gallon jars, before planting, viz: Ground limestone (98 per cent) 15 grams, containing 8¼ grams of pure lime; dried blood (12 per cent) 6½ grams, containing 0.78 gram nitrogen to supply nitrogen. "Banner Dissolved Bone" (24 per cent P_2O_5) 3.8 grams, containing 0.4 gram phosphorus or 20.0 grams fine ground Tennessee phosphate (28 per cent P_2O_5), containing 2.46 grams of phosphorus to supply that element. Sulfate of potash (54 per cent K_2O) 3.2 grams, containing 1.43 gram potassium to supply potassium. Manure, 35 grams of the dried and powdered material.

The 2-gallon pots received half these quantities.

Banner Dissolved Bone is a precipitated tricalcium phosphate, containing only about ¼ of one per cent of nitrogen and potash, respectively. It is not a "dissolved bone" in the usual sense, not having been treated with acid, and is not acid.

In the following tables, N. stands for nitrogen, P. for phosphorus and K. for potassium. Where there are two pots without fertilizer, the average of their yields is used in calculating the increase. The minus sign (—) before a number in the columns headed "Increase" means that there was *decrease,* instead of increase, in the yield.

SERIES NO. I.—1909-10, TOBACCO. FOUR-GALLON POTS.

Pot No.	Fertilizer	Yield of stalks and leaves. Grams per pot.	Increase Grams per pot	Per cent
352	None	12.8		
353	None	14.7		
354	Limestone	12.0	—1.75	—12.7
355	N	20.3	6.55	47.6
356	P	10.0	—3.75	—27.2
357	K	13.8	.05	0.4
358	N & P	21.1	7.35	53.4
359	N & K	21.2	7.45	54.2
360	P & K	7.9	—5.85	—42.5
361	N, P & K	22.1	8.35	60.7
362	Rock Phosphate	13.2	— .55	— 4.0
363	Manure	9.7	—4.05	—29.4
364	Rock phosphate and manure	10.3	—3.45	—25.1

SERIES NO. I.—1910-11, OATS AFTER TOBACCO. FOUR-GALLON POTS.

Pot No.	Fertilizer	Whole crop yield. Grams per pot.	Increase Grams per pot.	Grain yield Grams per pot.	Increase Grams per pot.	Per cent
352	None	50.		10.4		
353	None	45.		9.8		
354	Limestone	61.	13.5	13.5	3.4	33.6
355	N	63.	15.5	15.0	4.9	48.5
356	P	83.	35.5	15.0	4.9	48.5
357	K	64.	16.5	11.4	1.3	12.9
358	N & P	104.5	57.0	27.7	17.6	174.3
359	N & K	82.0	34.5	18.7	8.6	85 1
360	P & K	86.0	38.5	14.4	4.3	42.2
361	N, P & K	124.0	76.5	25.0	14.9	147.5
362	Rock phosphate	68.5	21.0	13.4	3.3	32.7
363	Manure	93.5	46.0	16.5	6.4	63.4
364	Rock phosphate and manure	84.0	36.5	15.4	5.3	52.4

SERIES NO. 11.—1909-10, CLOVER. TWO-GALLON POTS.

Pot No.	Fertilizer	Weight of three cuttings. Grams per pot.	Increase Grams per pot	Per cent
366	None	16.		
367	Limestone	20.4	4.4	27.5
368	N	19.4	3.4	21.3
369	N and limestone	15.7	—0.3	—1.9
370	P	32.1	16.1	100.6
371	P and limestone	43.1	27.1	169.4
372	K	21.7	5.7	35.6
373	K and limestone	19.8	3.8	23.8
374	N and P	31.2	15.2	95.0
375	P and K	24.8	8.8	55.0
376	N and K	15.3	—0.7	—4.4
377	N, P and K	35.1	19.1	119.8
378	Rock phosphate	30.8	14.8	92.5
379	Manure	25.7	9.7	60.6
380	Manure and rock phosphate	27.6	11.6	72.6
381	Manure and limestone	25.0	9.0	56.3

SERITS NO. II.—1910-11, TOBACCO AFTER CUOVER.
TWO-GALLON POTS.

Pot No.	Fertilizer	Stalks and leaves Grams per pot	Increase Grams per pot	Per cent
365	None	3.8		
366	None	3.7		
367	Limestone	5.0	1.25	33.3
368	N	6.2	2.45	65.3
369	N and limestone	5.3	1.55	41.3
370	P	4.6	.85	22.7
371	P and limestone	5.5	1.75	46.9
372	K	7.3	3.55	94.7
373	K and limestone	4.5	.75	20.0
374	N P	7.0	3.25	86.7
375	P K	1.1	—2.65	—70.7
376	N K	5.9	2.15	57.3
377	N P K	7.5	3.75	100.0
378	Rock phosphate	7.4	3.65	97.3
379	Manure	9.5	5.75	153.3
380	Manure and rock phosphate	7.6	3.85	102.4
381	Manure and limestone	4.2	.45	12.0

SERIES NO. III.—1909-10, WHEAT. FOUR-GALLON POTS.

Pot No.	Fertilizer	Whole crop yield, grams per pot.	Increase Grams per pot	Grain yield Grams per pot	Increase Grams per pot	Per cent
382	None	34.3	....	11.8	....	....
383	None	35.5	....	12.0	....	....
384	N	41.5	6.6	15.2	3.3	27.7
385	P	44.6	9.7	14.6	2.7	22.7
386	K	47.7	12.8	15.0	3.1	26.1
387	N & P	70.4	35.5	22.5	10.6	89.1
388	N & K	61.2	26.3	20.6	8.7	73.1
389	P & K	50.6	15.7	16.2	4.3	36.1
390	N, P & K	74.4	39.5	26.3	14.4	121.0
391	Rock phosphate	45.6	10.7	15.7	3.8	31.6
392	Manure	44.5	9.6	16.2	4.3	36.1
393	Manure and rock phosphate	36.3	1.4	14.9	3.0	25.2

SERIES NO. III.—1910-11, CLOVER AFTER WHEAT. FOUR-GALLON POTS.

Pot No.	Fertilizer	1st cutting Grams per pot	2nd cutting Grams per pot	Total Grams per pot	Increase Grams per pot	Per cent
382	None	13.	15.2	28.2	....	....
383	None	14.6	15.9	30.5	....	....
384	N	14.7	15.5	30.2	8.50	2.9
385	P	45.8	24.5	70.4	41.05	139.9
386	K	12.4	17.0	29.4	.05	0.2
387	N & P	51.2	21.5	72.7	43.35	147.7
388	N & K	17.7	19.3	37.0	7.65	26.1
389	P & K	49.3	22.0	71.3	41.95	143.0
390	N, P & K	44.0	25.5	69.5	49.15	136.8
391	Rock phosphate	32.2	21.0	53.2	23.85	81.3
392	Manure	46.5	25.0	71.5	42.15	143.6
393	Manure and rock phosphate	36.5	24.5	61.0	31.65	107.8

These results are reported here as being interesting and suggestive of what may be expected from the use of fertilizers in the field, though it is to be remembered that pot experiments and field results are not always concordant.

As the experiments are being continued, a discussion of them will not be attempted at this time. It may be noted, however, that, on the whole, phosphorus decidedly increased the yields of wheat, oats and clover, but not that of tobacco. That nitrogen decidedly increased the yields of wheat, oats and tobacco, but not that of clover. That potassium moderately increased the yields of wheat and oats and slightly increased that of clover, but did not have a marked effect on that of tobacco. Rock phosphate, used alone, gave consistent gains, except with tobacco. Used with manure, however, its effect seems to have been negative, contrary to the usual teaching. Limestone produced moderate increase with oats and clover and with tobacco following clover. Used with phosphorus on clover there was a decided increase over the pot where phosphorus alone was tried.

SOIL SURVEY OF THE MARRS FARM

HENDERSON COUNTY.

BY S. C. JONES.

This farm lies in the northeastern part of Henderson county, ten miles east of Henderson and one mile north of the Henderson-Owensboro pike. It is almost a perfect rectangle and is about twice as long as wide, and lies south of the junction of the Spottsville and Bluff City roads. Lick creek and Mosley's branch form the southwest boundary. The farm contains 300 acres.

TOPOGRAPHY AND DRAINAGE.

The farm contains two phases of topography, viz: the rolling uplands lying mainly in the northwestern portion of the farm and the flats or bottoms lying mainly in the southeastern portion of the farm. The natural drainage of the flat portion and even of portions of the uplands is very poor. This farm has good outlets for artificial drainage and when the proposed system is completed bad drainage conditions will no doubt be eliminated.

SOILS.

While this farm lies in the Western Coalfield and is doubtless underlain with coal, the soil, even that covering the upland, is probably largely of transported origin.

SOIL TYPES.

Although the soils of this farm differ in some respects from those of Webster county, considering their origin and chemical and physical nature, they agree more or less and may be justly correlated. Three types have been outlined, two in the low lands and one in the upland. Naming in order of area they are as follows:

	Acres	Per Cent.
Yellow silt loam (upland)	114	38.00
Gray clay loam (bottom)	97	32.66⅔
Gray silt loam (bottom)	88	29.33⅓

YELLOW SILT LOAM (UPLAND.)

This type covers the upland which occupies mainly the northwestern portion of the farm and contains a total area of 114 acres. The farm is only a few miles from the Ohio and Green rivers, and while the soil of the upland is very similar in its appearance to the soils farther south in the Coal Measures, they are very deep and appear in some places along the roads in this vicinity to possess properties characteristic of loess or transported soil. The surface is a yellowish or grayish silt loam of varying depth ranging from 6 to 10 inches. In places there are "scald" or worn spots on which clover is an absolute failure. Where these spots are found the surface soil appears to have been removed by erosion, leaving the sub-soil exposed. These "scalds" are very easily detected because of their red color which is rather typical of the more clay-like sub-soil.

The following tables contain the results of the chemical analyses, made by the Experiment Station chemists, of samples of both surface and sub-soil, one from the "scald" spots and the other from the natural soil:

Chemical Analysis of the Soils from the "Scald Spots,"

calculated as Per cent of the Moisture-free Samples.

	Surface 0 to 6"	Subsoil 6-18"
Laboratory number	36219	36220
Total nitrogen	.060	.038
Total phosphoric acid	.0975	.1012
Phosphoric acid dissolved by n/5 nitric acid (Available)	.0009	.0006
Total potash	1.64	1.80
Potash dissolved by n/5 nitric acid (Available)	.013	.0223
Lime dissolved by same	.095	.059
Acidity calculated as lime required	.081	.1835

Chemical Analysis of the Natural Soil,

calculated as Per Cent of the Moisture-free Samples.

	Surface 0-6"	Subsoil 6-12"
Laboratory number	36221	36222
Total nitrogen	.072	.048
Total phosphoric acid	.0775	.085
Phosphoric acid dissolved by n/5 nitric acid (Available)	.0008	.0005
Total potash	1.53	1.74
Potash dissolved by n/5 nitric acid (Available)	.0229	.0197
Lime dissolved by same	.103	.146
Acidity calculated as lime required	.006	.008

Figuring from the apparent specific gravity as determined from the correlated type in Webster county, there is over an acre to a depth of 6 inches approximately 1,900,000 pounds of soil, while in the succeeding 12 inches of sub-soil (6 to 18 inches) there is approximately 3,800,000 pounds of soil. Figuring on this basis and expressing the amounts of plant food in terms of the element the surface soil from the "scald" spots contains 1140 pounds of nitrogen, 809 pounds of total phosphorus, anl 25,863 pounds of total potassium, while in the subsoil (6-18 inches) there is 1,444 pounds of total nitrogen, 1,680 pounds of total phosphorus and 56,172 pounds of total potassium. This soil requires 1,539 pounds of lime (CaO) to neutralize the acid in the surface and 6,973 pounds to neutralize the acid in the subsoil.

In the surface soil the fifth normal nitric acid solution shows an availability of 0.92 per cent of the total phosphorus, or 7.47 pounds per acre, 0.79 per cent of the total potassium, or 205 pounds per acre, while in the subsoil it shows an availability of 0.59 per cent of the total phosphorus, or 9.69 pounds per acre, 1.2 per cent of the total potassium, or 703 pounds per acre.

The natural soil contains in the surface 1,368 pounds of nitrogen, 643 pounds of total phosphorus and 24,128 pounds of total potassium to the acre, while the subsoil (6-18 inches) contains 1,824 pounds of nitrogen, 1,411 pounds of total phosphorus and 54,879 pounds of total

potassium. This soil requires 114 pounds of lime (CaO) to neutralize the acid in the surface soil and 304 pounds to neutralize the acid in the subsoil.

In the surface the fifth normal nitric acid solution shows an availability of 1.03 per cent of the total phosphorus, or 6.64 pounds per acre, 1.49 per cent of the total potassium or 361 pounds, while in the subsoil it shows an availability 0.59 per cent of the total phosphorus or 8.3 pounds per acre, 1.13 per cent of the total potassium, or 621 pounds per acre.

The soil from the "scald" spots is poorer in total nitrogen and richer in total phosphorus and potassium than the natural soil, but has a smaller per cent of the total phosphorus and potassium available. Both the surface and subsoil of the natural soil are only slightly acid, while those from the "scald" spots are strongly acid. This is quite probably the reason for the clover failure.

GRAY CLAY LOAM BOTTOM.

This type includes 98 acres or slightly less than one-third of the entire farm. It is a transported soil and is rather characteristic of the bottoms along Green river and its tributaries in the Western Coalfield. It has a rather wide and diversified origin, having been derived from a series of geological formations representing principally the carboniferous rocks.

The land as a rule is rather flat; however, in places it has undergone a slight erosion. It is known by the farmers as "post oak" although this area appears to produce a larger type of oak than is commonly found.

The surface is a gray clay loam or loam underlain with a waxy clay subsoil varying from a yellow to a bluish gray color. In many places on the surface the soil is rather silty to a depth of 3 or 4 inches. Water does not stand on this soil, yet the natural drainage is poor. The following analyses were made by the Experiment Station chemists:

Chemical Analyses, calculated as Per Cent of the Moisture-free Samples.

	Surface 0-6"	Subsoil 6-18"
Laboratory number	36217	36218
Total nitrogen	.076	.056
Total phosphoric acid	.0787	.0412
Phosphoric acid dissolved by n/5 nitric acid (Available)	.0005	.0004
Total potash	1.42	2.12
Potash dissolved by n/5 nitric acid (Available)	.0085	.0075
Lime dissolved by same	.078	.070
Lime required to neutralize acid	.080	.316

Figuring from the apparent specific gravity as determined from the correlated type in Webster county, there is over an acre to a depth of 6 inches approximately 1,800,000 pounds of soil, while in the succeeding 12 inches (6 to 18 inches) there is approximately 3,700,000 pounds of soil. Figuring in pounds per acre there is in the surface soil 1,368 pounds of nitrogen, 619 pounds of phosphorus and 21,215 pounds of potassium per acre, while in the subsoil (6-18 inches) there is 2,072 pounds of nitrogen, 666 pounds of total phosphorus and 65,105 pounds of total potassium.

In the surface the fifth normal nitric acid solution shows an availability of 0.63 per cent of the total phosphorus, or 3.93 pounds per acre, 0.59 per cent of the total potassium, or 127 pounds per acre, while in the subsoil it shows an availability of 0.99 per cent of the total phosphorus, or 6.46 pounds per acre, 0.35 per cent of the total potassium, or 230 pounds per acre. The surface soil requires 144 pounds of lime (CaO) to neutralize the acid, while the subsoil requires 11,692 pounds of lime to neutralize the acid.

GRAY SILT LOAM BOTTOM.

This type includes 88 acres or slightly less than 30 per cent of the farm. This is a transported soil and is quite variable. It is derived principally from the immediate upland and in its physical nature is very similar to it in many respects. In the low places, along the drainage mains the soil is practically a yellow brown silt

loam. Since the land has been under cultivation much of this brown soil has been covered by the yellow or gray soil from the upland. Taking the area as a whole the surface soil is in the main a grayish or yellowish silt loam 8 inches or more in depth. The subsoil is probably more variable than the surface. Just north of the gray clay loam area the subsoil is rather clay-like, while in other places it is very similar to that of the upland, resembling somewhat a second bottom. From this place two samples were taken for chemical analyses, one from the surface and one from the subsoil. Also samples were taken from the first bottom. The analyses were made by the Experiment Station chemists:

Chemical Analyses of Soils from First Bottom, Calculated as Per Cent of the Moisture-free Samples.

	Surface 0-6"	Subsoil 6-18"
Laboratory number	36225	36226
Total nitrogen	.084	.062
Total phosphoric acid	.0825	.0757
Phosphoric acid dissolved by n/5 nitric acid (Available)	.0013	.0013
Total potash	1.42	1.41
Potash dissolved by n/5 nitric acid (Available)	.0165	.0149
Lime dissolved by same	.146	.160
Acidity calculated as lime	.003	.0005

Chemical Analyses of Soil from Second Bottom, Calculated as Per Cent of the Moisture-free Samples.

	Surface	Subsoil
Laboratory number	36223	36224
Total nitrogen	.066	.044
Total phosphoric acid	.0725	.0725
Phosphoric acid dissolved by n/5 nitric acid (Available)	.017	.0012
Total potash	1.24	1.37
Potash dissolved by n/5 nitric acid (avail.)	.0181	.0155
Lime dissolved by same	.059	.061
Acidity calculated as lime	.0145	.0695

Figuring from the apparent specific gravity as determined from the correlated type in Webster county, there is over an acre to a depth of 6 inches, approximately 1,900,000 pounds of soil, while in the succeeding 12 inches (6-18 inches) there is approximately 3,800,000 pounds of soil.

Figuring in pounds per acre the soil from the first bottom contains in the surface 1,596 pounds of nitrogen, 685 pounds of total phosphorus, and 20,215 pounds of total potassium, while the subsoil contains 2,356 pounds of nitrogen, 1,245 pounds of total phosphorus and 42,330 pounds of total potassium.

In the surface the fifth normal nitric acid shows an availability of 1.58 per cent of the total phosphorus, or 10.79 pounds per acre, 1.22 per cent of the total potassium, or 260 pounds per acre, while in the subsoil it shows an availability of 1.70 per cent of the total phosphorus, or 21.59 pounds per acre, 1.1 per cent of the total potassium, or 470 pounds per acre. The surface soil requires 57 pounds of lime (CaO) to neutralize the acid, while the subsoil requires only 9.5 pounds.

The soil from the second bottom contains in the surface 1,254 pounds of nitrogen, 501 pounds of total phosphorus and 19,555 pounds of total potassium, while the subsoil contains 1,672 pounds of nitrogen and 1,002 pounds of total phosphorus and 43,209 pounds of total potassium. The surface soil required 275 pounds of lime (CaO) to neutralize the acid, while the subsoil requires 2,641 pounds.

In the surface soil the fifth normal nitric acid shows an availability of 2.8 per cent of the total phosphorus, or 14.11 pounds per acre, 1.45 per cent of the total potassium, or 285 pounds per acre, while the subsoil shows an availability of 1.9 per cent of the total phosphorus, or 19.9 pounds per acre, and 1.13 per cent of the total potassium, or 489 pounds.

Chemical Analysis of Soils from Marr's Farm.

Plant food expressed in pounds per acre.

"Scald Spots" Where No Clover Grows.

(Yellow Silt Loam Upland.

	Total Nitrogen	Total Phosphorus	Avail. Phosphorus	Total Potassium	Avail. Potassium	CaO	Lime required to neutralize acid.
Surface soil	1140	809	7.47	25,863	205	1,805	1,539
Subsoil	1444	1680	9.96	56,172	703	2,242	6,973

Natural Soil—Where Clover Grows Well.

(Yellow Silt Loam Upland.)

	Total Nitrogen	Total Phosphorus	Avail. Phosphorus	Total Potassium	Avail. Potassium	CaO	Lime required to neutralize acid.
Surface soil	1368	643	6.64	24,128	361	1,957	114
Subsoil	1824	1411	8.3	54,879	621	5,548	304

"Post Oak" Soil.

(Gray Silt Loam—Bottom.)

	Total Nitrogen	Total Phosphorus	Avail. Phosphorus	Total Potassium	Avail. Potassium	CaO	Lime required to neutralize acid.
Surface soil	1368	619	3.93	21,215	127	1,404	144
Subsoil	2072	666	6.46	65,105	230	2,590	11,692

"First Bottom" Soil.

(Yellow or Gray Silt Loam.)

	Total Nitrogen	Total Phosphorus	Avail. Phosphorus	Total Potassium	Avail. Potassium	CaO	Lime required to neutralize acid.
Surface soil	1596	685	10.79	21,215	260	2,774	57
Subsoil	2356	1245	21.59	42,430	470	6,080	9.5

"Second Bottom" Soil.

(Yellow or Gray Silt Loam.)

	Total Nitrogen	Total Phosphorus	Avail. Phosphorus	Total Potassium	Avail. Potassium	CaO	Lime required to neutralize acid.
Surface soil	1254	501	14.11	19,555	285	1,121	275
Subsoil	1672	1002	19.9	43,209	489	2,318	2,641

This farm has been under cultivation for practically fifty years and until recently has been very poorly managed as is evidenced by its low nitrogen content and badly worn condition. Like all land in Western Kentucky, it is poor in total phosphorus and rich in total potassium. As shown by the fifth normal nitric acid solution every place or type of soil on the farm is poor in available phosphorus. According to the test for acid all of the soils are more or less acid. The "scald spots" of the upland and the gray silt loam (post oak) of the bottom are strongly acid. Also the subsoil of the "second bottom." The poor growth of legumes on this farm is doubtless largely due to the acid condition of the soils.

Then, in order to grow legumes, which is absolutely necessary if this land is to be built up, lime must be added to correct the acid condition of the soils. It may be added either in the form of burned lime or ground limestone, the latter being preferred because it does not have the caustic effect of the burned lime. An application of from one to four tons per acre of finely ground limestone would be advisable, the larger amounts of course being added to the strongly acid areas.

We have seen, furthermore, that if this land is to be made fertile, its nitrogen and phosphorus contents must be increased and a larger per cent of the great store of inert potassium made available. How is this to be accomplished? Because of the high price of commercial nitrogen the farmer cannot afford to buy this element for general farm crops. It can be added to the soil much more cheaply from the large store in the atmosphere by growing clover and other legumes and at the same time accumulate organic matter which will aid in rendering available the inert phosphorus and potassium. The legumes may be turned under directly or fed as hay and the manure returned to the soil, the latter, however, being regarded more profitable. Then assuming that potassium may be made available only phosphorus remains to be purchased. Phosphorus may be purchased in the form of acid phosphate, bone meal or ground rock phosphate. Ground rock phosphate is much the cheapest form and will no doubt be more profitable with the proper system of crop rotation employed.

SOIL SURVEYS OF THE HARTFORD, MADISONVILLE AND CENTRAL CITY QUADRANGLE.

A SOIL SURVEY OF THE HARTFORD QUADRANGLE.

BY S. C. JONES.

This quadrangle lies in the Western Coalfield within parallels 37° 15′ and 37° 30″ north latitude and meridian 86° 45″ and 87° west longitude. This area lies almost wholly in Ohio county, including on the southeast a small portion of Butler county and on the southwest a small portion of Muhlenberg county.

Like all of the Western Coalfield the geology is composed of alternating strata of sandstones, sandy shales, clays, slaty materials and a number of veins of coal of varying thickness and character. When these formations weather and the resulting materials intermingle soils of a rather uniform nature are formed.

The topography of the country, included in this quadrangle is quite various, the lowest altitude along the streams being 380 feet above sea level and the highest in the upland slightly more than 600 feet, giving a range in altitude to about 240 feet.

There are three phases of topography represented in the area, 1st the low flat bottom lands, 2d the gentle rolling or undulating upland, and 3d the broken or dissected hilly area.

GENERAL DRAINAGE.

The southern half of the quadrangle is divided by the Green river and its tributaries, Lewis creek, Pond Run, Spur creek, Bull Run, Slaty creek, and Indian Camp creek, while the northern half is drained by Rough river and its tributaries, Muddy creek with its several prongs, viz: North Fork, Elmlick creek, Pigeon creek, Threelick Fork, Beaverdam creek, etc., and Mill Run, Morrison Run, Big Run, Walton creek and No creek.

SOIL TYPES.

Out of a total of 247 square miles of territory in the Hartford Quadrangle there are 172.19 square miles containing soil of residual origin and 74.81 square miles of transported origin. The residual soil occupies the upland and has been formed from the insoluble materials remaining in place after the disintegration of the overlying rocks, thus forming a cover over the deeper unaltered rocks, while the transported soil occupies the bottom land having been carried in by the water of the small streams and rivers.

Classifying the soils of the residual and transported areas according to origin, topography and physical nature, such as their content of sand, silt, clay, organic matter, color, etc., five types are recognized, three in the transported area and two in the residual. Naming in order of area, these five types are as follows:

	Sq. Mi.	Acres.	Per Cent.
Yellow silt loam (hilly)	135.	86,400	54.65
Gray silt loam (bottom)	42.13	26,963	17.05
Yellow silt loam (undulating)	37.19	23,801	15.05
Gray silt loam (river bottom)	20.25	12,960	8.19
Yellow clay loam (river bottom)	12.43	7,965	5.03

YELLOW SILT LOAM (HILLY).

More than half of the territory embraced in the Hartford quadrangle comes under this type, 86,400 acres or 54.65 per cent of the entire area. It occupies the dissected or hilly portion of the area which is interspersed with a number of strips of bottom of a greater or lesser width extending along the streams. There is an undulating area some three or four miles in width made up of the wide bottoms and undulating upland, extending across the quadrangle in a northwest and southeast direction which divides the hilly region into practically two separate areas. The hills vary in height from 40 to 200 feet, the highest rising some 200 feet above the lowest bottom. They are usually not very large and present a somewhat serrated appearance, with usually narrow ridges.

In its origin the soil of this type is very closely related to the undulating yellow silt loam, the chief difference being that of topography which for cultivation separates them quite widely.

The surface soil is a yellowish or grayish silt loam with depth ranging from 6 to 8 inches. It is mellow and open and unless tramped when wet rarely breaks into clods and tills as nicely as a real sandy loam.

The subsoil is usually more clay-like in its properties unless in places where the soil is shallow and the sandrock lies near the surface, in which case the subsoil becomes quite sandy. However, as a rule, at from 10 to 15 inches it has a bright yellow or reddish color with gray streaks and in places iron strains, where at from 15 to 30 inches it becomes decidedly more plastic because of a greater content of clay.

It is a well drained soil, but at the same time possessing fairly good water holding properties. The surface soil is very open and porous, allows the rain water to enter easily which is stored up in the more clayey subsoil. However, the capacity of the surface soil to hold moisture could be greatly increased by incorporating large quantities of vegetable matter which originally is very much lacking.

The native timber found growing on this type consists of the different varieties of oak, beech, maple, hickory, sassafras, persimmon and in some places walnut. The valuable timber has practically all been cut off of the hills, and they are now covered with shrubs and a second growth of small trees.

The soils of this area are not so badly washed as are the hills in some other sections of the Western Coalfield. They do not seem to have been cultivated so long before being turned back to a growth of shrubs and wild grasses. Only a comparatively small proportion of this area is now under cultivation. Corn, wheat, tobacco and hay are the principal crops grown. Not nearly as much tobacco is grown as in the counties just west of Ohio county. The yield of corn varies from 15 to 20 bushels per acre, that of wheat from 10 to 15, and tobacco from 500 to 1,000 pounds. Hay is made from clover, cow peas, timothy and red top and yields an average of about one ton per acre.

These hills should be kept in grass, timber and orchards. The land washes very badly when cultivated continuously. The Japanese clover is now the chief grass on these hills. It is inadequate for grazing because of not appearing until late in the spring and dying out with the early frost in the fall and withers and dies during only moderate drouths. With grass, able to resist drouths, that will make a sod on the silty or sandy soil and that will grow early in the spring and late in the fall, the hills of the Western Coalfield could be made a profitable country for grazing. All kinds of fruits do well in the upland soils in this area and the location is such that there is seldom a year when fruit is a failure because of freezes and frost. The rough and badly eroded areas should be planted in a quick growth of timber, such as the post-locust, which after twenty years would be yielding a handsome profit for the owner.

Yellow Silt Loam (Undulating).

The soil of this type includes 23,801 acres or 15.05 per cent of the total area. The largest areas border on the Muddy creek bottoms, the largest lying north of Beaverdam, embraced between Beaverdam and Muddy creek; the next in size lies just east of Hartford, north of Muddy creek. The remainder includes numerous small tracts or patches scattered in various places over the area.

This type is gently rolling and occupies the low upland areas, the gentle slopes and the broad ridges. Its origin is the same as that of the hilly area, though the soils are usually much deeper, the depth ranging from 12 to 20 feet to native rock, while on the hill sides rock is often found within two or three feet of the surface.

The surface soil is a yellowish or grayish silt loam varying in depth from 6 to 10 or 12 inches. It is very loose and open and generally lies rolling enough to afford fairly good natural drainage, though the flat portions of the soil is rather gray, indicating, of course, the need of drainage.

The subsoil, because of less favorable drainage, is slightly more gray in color than that of the hills, otherwise in their nature they resemble each other rather

closely. On the undulating soils maple, beech and walnut are found more frequently than on the hills.

A much larger proportion of this type is under cultivation, but practically the same crops are grown with of course much better yields. Corn yields from 20 to 60 bushels per acre, wheat from 10 to 30 bushels, and tobacco from 800 to 1,400 pounds. Clover and grasses do well on fresh land, but not so well on old land, unless well manured. This land is valued at from $25 to $50 or $60 per acre, while the hill land is valued at from $5 to $25, in both cases the price depending on location, state of cultivation, etc.

GRAY SILT LOAM. (BOTTOM).

This is a type that is quite common along all the small streams in the Western Coalfield. In this quadrangle there are 26,963 acres or 17.05 per cent of the whole area. It lies along the small streams and has been derived chiefly from the immediate upland. There has been considerable material deposited in these bottoms since the hill land was cleared.

The surface soil varies from a gray to a yellowish silt loam, usually 8 inches or more in depth. In the low bottoms where water stands it is gray and crawfishy, while where better drained it is a yellowish color, and is usually underlain by an incoherent silt of mealy texture, while the low wet areas are underlain by a more plastic material.

In the portion of these bottoms lying near the rivers the soil is somewhat modified by an intermingling of material from the back water, which renders the soil slightly more plastic and clayey in its nature. These places are so low that the overflow and back water render them practically worthless for cultivation. If it were not for the back water, ditching with a system of tile drainage would probably carry off the overflow and this land could no doubt be cultivated. Such an area extends from the mouth of Muddy creek almost up to Beaverdam. The land lying further back from the rivers in these bottoms can be reclaimed, unless during exceptionally rainy seasons, by a well planned system of ditching or tiling.

The native growth in these bottoms consists of black oak, red oak, sweet gum, sycamore and elm. Corn and hay are practically the only crops grown and because of such poor drainage the yields are low.

This type is found in the bottoms of Green and Rough rivers and differs from the soil of the bottoms along the small streams, in that the materials composing the soil are derived from a number of formations differing quite widely in their character.

As outlined in the map, there is in this type 12,960 acres or 8.19 per cent of the total area. The soil of the area varies somewhat in its physical nature, that near the river being usually more sandy and becoming more silty towards the upland. The silty strips along the river vary from a gray sandy loam to a brown sandy loam, ranging from 10 to 30 inches in depth. These patches are very productive and because of lying from 5 to 8 feet higher than the bottom away from the river the drainage is fairly good. Near the hills there is often found a thin deposit of bluff wash underlain with gray silty material, although in places rather clayey in its nature. The bottom along Thorofare creek varies from a yellow to a gray silt loam, while that along Bull run and Slaty creek lies lower and is more clayey in its nature.

The land along Rough creek overflows more often than that along Green river. For the last five years crops have been drowned out almost every year. With a good system of drainage in the bottoms where there is no overflow the water after a freshet will be more rapidly removed and conditions made more favorable for growth of crops.

A growth of beech predominates to such an extent on this land that it is often known as "beech land." In the low places black and sweet gum are usually found.

Corn and hay are about the only crops grown, the yield depending on the amount of rainfall and drainage. Where the land is well drained and not injured by overflow water, corn will yield when well cultivated from 40 to 50 bushels per acre, where on poorly drained land practically no yield is obtained.

YELLOW CLAY LOAM. (RIVER BOTTOM).

This type, which has been deposited by overflows and by back-water, lies mainly along the larger streams. Of such soil there are 7,965 acres, or 5.03 per cent of the total area.

The surface soil, which is a yellow clay loam, varies from 8 to 10 inches in depth. This type is very closely related to the gray silt loam (river bottom), and occupies neighboring areas, but differs from it in containing more clay.

Practically the same sorts of crops are grown on the silt loam, with no material difference in yield.

SOIL SURVEY OF MADISONVILLE AND CENTRAL CITY QUADRANGLES.

These two quadrangles lie in the central portion of the Western Coalfield within parallel 37° 15′ and 37° 30′ north latitude and meridians 87° and 87° 30′ west longitude. This area includes the northern half of Muhlenberg, a small portion of southwestern Ohio, the southern portion of McLean and the northeastern portion of Hopkins counties.

The geology, topography, soils, native vegetation and methods of farming practiced in these two quadrangles are rather typical of the area included in the Western Coalfield.

The geology of this area is composed of alternating strata of sandstone, sandy shales, clays, slaty materials and a number of coals, and at certain horizons limestones of thickness varying from a few inches to 12 or 14 feet. The greatest thickness noted was in a ledge at Madisonville.

TOPOGRAPHY.

The contour lines on the topographical maps represent an interval of 20 feet. As shown by these lines the topography of the area included in these two quadrangles is quite variable. From the lowest to the highest contour there is a difference of 240 feet; the lowest representing the stream beds and having an altitude of 360 feet above sea level and the highest representing the

tops of the highest hills and having an altitude of 600 feet. The area may be divided into five different phases of topography: 1st the low, broad, flat bottom lands along the streams, mainly lying between the contours 380 and 400 feet; 2d the bottom land more than 400 feet above sea level along the small streams extending into the upland; 3d the undulating or gently rolling upland; 4th the rugged hilly areas where the county has been elevated and dissected; and 5th, high flat ridges at the summit of these hills.

GENERAL DRAINAGE.

The Central City Quadrangle is drained by Green and Rough rivers and their tributaries, Pond creek, Cypress creek, Elk creek, and Barnett creek, while the Madisonville quadrangle is drained by Pond river and its tributaries, Drake creek, Flat creek, Bratton creek, Narge creek, Elk branch, Long creek, Otter creek, Brier creek, Isaacs creek, etc.

The deep deposits of transported material in these wide bottoms prove that during past ages these streams occupied much lower geological horizons than they occupy at present. It is claimed that drillings have been made in these bottoms to a depth of 150 feet before striking native material.

SOIL TYPES.

The soils of thes two quadrangles are of two kinds, residual and transported. The upland or residual soils are very uniform in their physical character. Sandstone is the predominating material from which they are formed, and for this reason they do not vary a great deal in their physical composition; however, they do vary considerably in topography, which in fact determines their agricultural value. On this basis the upland soils have been divided into two types: 1st, the undulating or gently rolling country which can be cultivated when managed properly, without undergoing erosion; 2d, the rough hilly country which should be kept in timber and grass. The difference in the topography of these two types is not due to a difference in the nature of the material from which they are formed, but to a difference in

their elevation. The elevated portion being more susceptible to the agencies of erosion, has been quite badly dissected, while the less elevated portion has been more able to resist erosion.

The transported soils are also divided into two areas: 1st, the broad low flat bottoms, having an altitude less than 400 feet above sea level, and 2d, the narrow bottoms extending into the dissected region having an altitude greater than 400 feet. The types are described in order as given below:

	Sq. Mi.	Acres.	Per Cent.
Yellow silt loam (undulating)	139	88,960	28.1
Yellow silt loam (hilly)	120	76,800	24.3
Low flat bottom	213	136,320	43.1
Gray silt loam (bottom)	22	14,080	4.5

YELLOW SILT LOAM. (UNDULATING).

More than one-fourth of the territory embraced in the two quadrangles comes under this type, 88,960 acres, or 28.1 per cent of the entire area. Of the 139 square miles, 76 square miles lie in the Madisonville quadrangle and 63 square miles in the Central City.

The topography of this type is in the main gently rolling, though some of the lower areas are quite level. This type includes the low flat upland, the gently rolling upland and the broad flat ridges in the rough area.

The surface soil is a yellowish or grayish silt loam varying in depth from 6 to 10 inches. It contains a large per cent of silt and its capacity to hold moisture depends largely on the amount of organic matter present. A large proportion of this type has been cultivated for many years without much effort on the part of the farmers to incorporate vegetable matter.

The subsoil is more reddish in color and contains from 10 to 15 per cent more clay than the surface. It is rather compact, but is quite pervious to water.

The underlying rock is found at a depth ranging from 12 to 25 feet. This gives good storage space for under ground water which greatly facilitates the water supply of the soil.

The following table shows the results of mechanical analysis of both the surface and subsoil:

Mechanical Analyses of the Yellow Silt Loam.

(Undulating.)

		1	2	3	4	5	6	7	
Collector's Number	Depth Sampled	Gravel 1—2 mm.	Coarse Sand, 1—.5 mm.	Medium Sand, .5—.25 mm.	Fine Sand, .25—.1	Very Fine Sand, .1—.05 mm.	Silt, .05—.005 mm.	Clay, .05—.005 mm.	Total
		Pct. Cent.	Pct. Cent.	Pct. Cent.	Pct. Cent.	Pct. Cent.	Pct. Cent.	Pct. Cent.	Pct. Cent.
		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
8	0-6"	.2	1.3	.8	2.6	7.3	73.6	14.6	100.4
9	6-18"	.0	1.2	1.0	1.0	5.2	67.9	23.3	99.6
29	0-6"	3.4	2.8	.8	1.6	8.3	71.5	12.4	100.8
30	6-18"	2.8	2.4	.6	1.5	7.1	67.8	18.1	100.3
19	0-6"	.5	1.3	.5	1.7	4.3	80.9	10.	99.2
20	6-18"	.3	1.0	.6	1.6	7.3	65.9	23.1	99.8
12	0-6"	.7	1.7	1.2	3.2	3.8	77.0	11.5	99.1
13	6-18"	.9	1.8	1.2	2.9	3.1	71.0	17.2	98.1
Av. 4	Samples 0-6"	1.2	1.8	.8	2.3	5.9	75.8	12.1	
Av. 4	Samples 6-18"	1.0	1.6	.9	1.8	5.7	68.1	20.4	

The characteristic growth on this soil consists of the different varieties of oaks, hickory, beech, hard maple, sassafras, persimmon and walnut.

The principal crops grown are wheat, corn, tobacco and hay. Cow peas are grown very extensively for hay. The yield of corn averages from 25 to 30 bushels, tobacco

from 1,000 to 1,500 pounds, and hay from 1 to 2 tons. Much of the land in this type has been under cultivation from 50 to 75 years. At present from 35 to 50 per cent is under cultivation. For agricultural purposes it is valued at from $15 to $50 per acre, the price depending on the location and nature of the soil.

YELLOW SILT LOAM (HILLY).

In its origin this type is very similar to the yellow silt loam (undulating), the chief difference being that of topography. This type includes 120 square miles, or 24.3 per cent of the entire area, 48 square miles being in the Central City quadrangle and 42 square miles in the Madisonville quadrangle. The surface soil is a yellow silt loam varying from 6 to 8 inches in depth. Its physical composition is practically the same as that of the undulating type. The subsoil is somewhat darker in color than the surface and contains a larger per cent of clay. The soil covering this area is not generally so deep as that of the undulating area. In places sandstones lie near the surface and are reached with the sampling tube. Such samples of course have a high sand content.

The native growth consists largely of oak, sassafras and persimmon. Maple, beech and walnut are found much less abundantly than in the undulating area. A large per cent of this area has not yet been cleared, and usually contains a very poor growth of timber.

The same crops are grown on this type as are grown on the undulating type, though much smaller yields are obtained.

This land washes very badly and after being cultivated a few years is practically abandoned. For agricultural purposes it is valued at from $5 to $10 per acre.

On both of these types Japanese clover grows very luxuriantly, especially during seasonable summers, and is quite valuable for pasture. It is also valuable as a fertilizer in restoring nitrogen and vegetable matter to the soil.

THE LOW FLAT BOTTOM LAND.

In these two quadrangles there are 213 square miles, or 43.1 per cent of the total area of low flat bottom land lying below the four hundred foot contour line.

The materials composing this low flat land have been transported from areas along the waters of the Green river, Rough river and Pond river and have been carried in mainly by these streams. They flow through the Devonian, Waverly, St. Louis, Chester, and Coal Measures areas, hence the soils are largely an intermixture of materials of wide and diversified origin. However, the physical nature of the soils occupying a large portion of this area indicates that they have been derived largely from the Coal Measures. Much of the material composing these soils has been carried in by the rivulets and streams which drain the near-by upland.

These bottoms are generally rather flat and there are a number of low sandy areas. The largest swamps are found in the Central City quadrangle, in the bottom north of Central City in Muhlenberg and McLean counties. These swamps receive their water from the small streams and from the overflow of the rivers. Practically all this area has very poor natural drainage. During high water practically the entire area is submerged and even during dry summers the water table remains near the surface.

THE SOILS.

The soils of the bottom land are more diversified in their physical nature than those of the upland. Over a large portion of the area they vary from a fine sand to a fine sandy loam. In these phases the surface has a rather ashy gray color. The gray color is no doubt due to the leaching these soils have undergone.

They are usually underlain with a light gray, fine, sandy subsoil. These phases of soil usually lie back from the river in the vicinity of the upland. However, in some places they are found near the river.

Along the large streams soils varying from sandy loams to clay loams are often found. Along Rough creek in Ohio county there is a large area occupied by a brownish clay loam. Similar areas are found along

both Pond and Green rivers. They are usually underlain with a clay loam. These clay loams are usually rich in organic matter. Along the large streams where the bottoms are not so wide the sandy soils usually lie near the river and the heavier or loamy soils lie near the bluff or upland.

The different varieties of oak, the common beech, water beech, sweet gum, black gum, elm, hickory, etc., represent the characteristic vegetation of the bottom land. The larger portion of this area yet remains in timber, though of an inferior quality, the best having already been cut.

At present only a small proportion is under cultivation. The cultivated areas usually lie near the streams or in the vicinity of the upland. The large proportion of this area as it now exists is practically worthless for agricultural purposes. By introducing the proper system of artificial drainage practically all this land can be reclaimed. From the lowest to the highest points there is a difference of 40 feet, which will give ample fall for a system of drainage.

The fact that this land overflows practically every spring will render it even when drained, fit for only summer crops, such as corn, potatoes, cow peas, etc.

A farmer on Rough river bottom in Ohio county claims during favorable seasons without drainage to have produced 75 bushels of corn per acre. If this is true when this land is undrained, it should be made to produce 100 bushels when drained.

GRAY SILT LOAM (BOTTOM).

This type includes the bottom lying above the four hundred feet contour line. It includes mainly the narrow bottoms extending into the more dissected areas. There are in both quadrangles 22 square miles, 18 lying in the Central City and 4 in the Madisonville.

They have been transported almost entirely from the near-by upland. The soils of these bottoms are in the main a yellow or gray silt loam. They are usually deep and the subsoil often does not differ greatly from that of the surface unless in the wider bottoms where the drainage is poor, in which case both the surface and

subsoil are gray in color. Generally the natural drainage is fairly good in the narrow bottoms. However, in the wider, artificial drainage would no doubt be beneficial.

A large portion of this type is under cultivation, corn and hay being the main crops grown.

A PRACTICAL WAY TO SUPPLY PLANT FOOD TO OUR SOILS.

BY S. C. JONES.

Of the eighty known chemical elements entering into the composition of the earth and atmosphere only ten are essential to the life and growth of plants. These ten are carbon, oxygen, hydrogen, sulphur, iron, calcium, magnesium, potassium, nitrogen and phosphorus. Other elements are taken up by plants, such as silicon, sodium, chlorine, etc., but are not essential to their life and growth.

By elements here is meant simply the constituent parts of the soil and atmosphere that compose the food of plants.

Carbon and oxygen are taken into the leaves of plants from the air as carbon dioxide, while hydrogen, a constituent of water, is absorbed through their roots. The other seven elements, with the exception of nitrogen, have their source only from the soil, unless supplied artificially as manure or commercial fertilizers.

Though the atmosphere over every square inch of soil contains about 12 pounds of nitrogen, such crops as wheat, corn, tobacco, potatoes, in fact, all crops except "legumes" (clover, peas, beans, alfalfa, etc.), have access only to the small portion that exist in the organic matter of the soil.

Of the six elements, sulphur, iron, calcium, magnesium, potassium and phosphorus, the first four named occur in all soils in relatively large proportions and enter into the composition of plants in relatively small proportions, while potassium and phosphorus occur in soils in relatively small proportions and enter into plants in relatively large proportions. This is especially true of the element phosphorus.

From the facts stated above it is plain to be seen that the question of supplying plant food resolves itself into the three elements, nitrogen, phosphorus, and potassium.

In an acre seven inches deep there is approximately two million pounds of soil. Figuring on this basis the average of 24 samples of soil recently taken from different sections of the State show a total of 20,960 pounds of potassium, 678 pounds of phosphorus, and 1,509 pounds of nitrogen. While the majority of these samples were taken from the poorest soil areas in the State and are no doubt below the average, the relative proportion will in all probability remain about the same.

A fifty bushel crop of corn (stalks and grain) will take from an acre, 35 pounds of potassium, 75 pounds of nitrogen, and 11½ pounds of phosphorus. If it were possible to grow such crops every year until the plant food of this soil is exhausted there is enough potassium to last 598 years, enough phosphorus to last 59 years, and only enough nitrogen to last 20 years. This would seem to indicate that for corn on our average soils nitrogen is the limiting element. This is no doubt true on a large proportion of farms in the State, not only for corn, but for all grain crops; however, there are some soils in which phosphorus will give a larger increase than nitrogen even in grain crops. This depends on whether they have been cropped continuously with grain crops or whether systems of rotation have been employed in which nitrogen has been added by growing legumes. In this case phosphorus would be the limiting element.

The elements of plant food in a soil exists in the compound, that is in the combination with other elements, and only a fraction is available at any one time. The amount that is available depends upon the physical nature of the soil, that is, whether it is porous and open, or close and compact, whether well drained and upon the amount of vegetable matter it contains. Also the form in which the inert or unavailable plant food exists. If, for instance, the phosphorus exists in combination with iron and aluminum it is only slowly made available, even under favorable conditions, while if it exist in the form of lime or calcium phosphate it is quite readily made available under favorable conditions. Such conditions of course exist in open soils well drained and rich in vegetable matter.

In determining the available plant food the chemists of the Kentucky Station use what is known as a fifth-

normal nitric acid solution. This is a weak acid solution and is supposed to extract from a soil about the amount of potassium and phosphorus that is available to the plant. This amount is not always in proportion to the total amount that occurs in a soil. A soil rich in total plant food may have only a small amount of available plant food , while one that is poor in total plant food may have a large amount of available plant food.

This may be very well illustrated by giving the amount of total and available plant food determined for two lots of soils taken from two areas in Taylor county, in the soil investigations now being carried on in co-operation by the State Geological Survey and the Agricultural Experiment Station, results as obtained by the fertility chemist and as obtained in pot culture experiments being given in comparison. One of these soils, a red loam, was derived from rocks that belong to that portion of the Subcarboniferous known as the Waverly formation, while the other, a gray, fine, sandy loam, was derived from the mantle which overlies rocks of the St. Louis formation.

Figuring on the basis of two million pounds of soil to the acre, the red clay loam contains a total of 21,590 pounds of potassium, 2,280 pounds of nitrogen and 1,040 pounds of phosphorus. This soil contains 410 pounds of available potassium and 12 pounds of available phosphorus. The gray, fine, sandy loam contains a total of 18,870 pounds of potassium, 1,440 pounds of nitrogen, and 499 pounds of phosphorus. This soil contains 556 pounds of available potassium and 18 pounds of available phosphorus. The soil containing the smaller amount of total potassium and phosphorus has the larger amount of available.

Pot culture experiments were carried on with these soils in the soil fertility green house at the Experiment Station. Check pots, that is pots having no treatment, were kept, along with those having the different combinations of plant food (as nitrogen, phos., nitrogen and phos., and so on). Nitrogen was added in the form of dried blood, potassium in the form of potassium sulphate, and phosphorus in the form of Banner dissolved bone, which is a very available form of phosphate of

lime, without nitrogen or acid, and also in the form of finely ground rock phosphate.

Oats were grown in the pots and weighings were made of the mature grain from each pot.

Phosphorus added to the red loam soil in the form of Banner dissolved bone gave an increase of 15 per cent over the pots having no treatment, while in the form of ground rock phosphate it gave an increase of 22 per cent. Dried blood gave an increase of 50 per cent, while potassium sulphate gave a decrease of 17 per cent. Figuring the results for the elements when used in combination, nitrogen gave an increase of 82 per cent, phosphorus an increase of 66 per cent, and potassium a decrease of 14 per cent.

Phosphorus added to the gray, fine, sandy loam in the form of Banner dissolved bone gave an increase of 6 per cent, but when added in the form of finely ground rock phosphate it gave an increase of 12 per cent. Dried blood gave an increase of 18 per cent, and potassium sulphate gave an increase of 3 per cent. Figuring the results for the elements when used in combination, nitrogen gave an increase of 16 per cent, phosphorus an increase of 6 per cent, and potassium a decrease of 5 per cent.

Both of these soils are rich in both total and available potassium and the results obtained in the pot culture experiments indicate that potassium is not needed in the fertilizer. The results further indicate that nitrogen is the limiting element in both soils. While the red loam has more than twice as much total phosphorus as the gray, fine, sandy loam, it has only two-thirds as much available. This is no doubt the reason for phosphorus giving much better results in this soil than it gave in the gray, fine, sandy loam.

When phosphorus was supplied alone in the form of Banner dissolved bone the plants made a very rank growth at first, but later turned yellow and growth was arrested, but when the finely ground rock phosphate was supplied, the plants remained green and growth proceeded slowly during the whole growing period. This perhaps accounts for the finely ground rock phosphate giving better results than Banner dissolved bone. In four other soils available phosphorus was compared with the

finely ground rock phosphate and in three of these rock phosphate gave the best results. The soil in which the available phosphorus gave the best results was quite rich in nitrogen. To this fact the result may have been due.

Similar tests have been made with soils taken from different sections of the State outside the Blue Grass region proper. In five out of eight phosphorus gave better results than nitrogen; in two out of four with oats; in two out of three with wheat, and in one with tobacco.

In four out of eight tests with potassium, compared with no treatment a decrease in yield was obtained. The most marked increase was obtained when both phosphorus and nitrogen were used together.

It is doubtful, because of the different conditions existing, whether results obtained in the field on these soils would be identical with those obtained in the pots. However, they would no doubt agree in a general way; and are really significant in determining the needs of these soils.

The results pointed out above indicate that for general farm practice in which such crops as corn, wheat, oats and tobacco are grown, a profit may be obtained from an increase in the nitrogen and phosphorus content in the average soils of the State.

Now the question arises how can these deficient elements be supplied at a maximum of service and a minimum of cost?

Commercial nitrogen in the form of dried blood or sodium nitrate costs 15 to 20 cents a pound. Fifty bushels of corn takes from an acre of soil 75 pounds of nitrogen. It is evident from these facts that the farmer can not afford to buy commercial nitrogen for his corn crop. This is true for all farm crops. These crops must have nitrogen. How is it to be obtained?

It was stated above that the atmosphere over every square inch of soil contains about 12 pounds of nitrogen. There is formed on the roots of legumes (Peas, beans, clover, alfalfa, etc.), small nodules that are inhabited by very small beings called bacteria. These bacteria extract nitrogen from the atmosphere as it circulates through the soil. By adopting a system of rotation in which legumes are grown and fed as hay and the manure

returned to the soil, or by turning under directly as green crops, and as catch crops, it is estimated that nitrogen may be added to a soil for from 2 to 4 cents per pound. At the same time large quantities of vegetable matter is added, which in most soils is very badly needed. The decay of this vegetable matter will furnish organic acids which will render available potassium from the large store that exist in Kentucky soils. It will also render available the inert phosphorus.

Finally, the source of phosphorus is to be considered. It does not exist in the atmosphere and must come from some outside source. In the form of acid phosphate and steamed bone meal it will cost from 12 to 15 cents per pound. In commercial fertilizers the average farmer pays from 15 to 20 cents per pound. In the finely ground rock phosphate it can be purchased for from 3 to 4 cents per pound.

It has been argued that it is better to use the acid phosphate because it is readily available. But is it not much cheaper for the farmer to use the cheapest form of phosphate and make it available by turning under organic matter, as green crops and manure? This is nature's way of making available the phosphates of the soil which exist in the same form as rock phosphate.

There is spent annually by the farmers in Kentucky one and a quarter million dollars for commercial fertilizers. If one-half of this money were expended for finely ground rock phosphate and the other half for supplying vegetable matter and nitrogen, the soils of Kentucky could be made to yield much larger crops than they now yield, and at the same time become richer in plant food instead of poorer as is now the case where commercial fertilizers are used.

SOILS OF MEADE AND BRECKINRIDGE

BY

S. C. JONES.

These counties lie in the northwestern part of the State on the Ohio River within parallels 38° 15′ and 37° 40′ W. longitude and 87° 20′ and 86° N. latitude.

These counties have very poor roads, in spite of the fact that in a large portion of the area there is an abundance of road making material close at hand. At present there is only about 10 miles of hard road in the two counties. By building good roads land would be made to enhance in value and farming would become more intensive and profitable. At present farming is the chief industry. The many large and poorly cared for orchards are evidence that formerly fruit growing was an important industry. With proper care of these orchards, and with devices for spraying, it should still be made one of the most profitable phases of agriculture.

GEOLOGY.

The Chester and St. Louis are the predominating areas and constitute more than nine-tenths of the total area contained in the two counties. From the standpoint of territory the other farm areas are of minor importance.

The Chester and St. Louis are known locally as the "sandstone" and "limestone" areas, though each contains within itself quite diversified geology. This is especially true of the Chester group. The area representing this group is made up of a series of sandstones, alternating with limestone and clays which are sometimes locally known as marls.

In some places the sandstones are very massive, having a thickness of from 50 to 75 feet, generally, however, much less.

The area comprising the Chester group occupies the greater portion of Breckinridge county and a large portion of Western Meade.

The St. Louis or limestone area occupies almost the entire eastern two-thirds of Meade county and extends over into Breckinridge county in the vicinity of Irvington, Webster and Rosetta and is found along many of the streams in the Chester area of both counties.

GENERAL TOPOGRAPHY.

The general topography of these two counties is rather diversified, the altitude varying from 375 feet to almost 825 feet, a difference of 450 feet from the lowest to the highest points.

The Chester group occupies the highest altitude and contains many high hills and many small level planes. Along the streams the country is badly broken and in many localities splendid exposures of the different divisions of this group are furnished.

The limestone area taken as a whole has a more level topography than the Chester; however, the numerous depressions or sink holes contained within this area, give it a very irregular and broken surface.

DRAINAGE.

In the geological areas comprising these two counties there are two systems of drainage, viz., surface and underground. The Chester area is traversed by many streams and has surface drainage, while the St. Louis area has but few streams and is drained mainly by underground chnnels. There are large areas in this formation where no streams are found.

SOILS.

The soils in Breckinridge and Meade counties are rather diversified, though in a general way are included mainly in two great areas. One the sandstone area of the Chester group and the other the limestone area of the St. Louis. Of course the other geological formations, the river alluvium or bottom land and coal measures form other minor areas.

In the Chester series of rocks the several alternating sandstones, limestones and clays furnish the surface ex-

posures in the different parts of the country. These exposures are very local and in many places involve only small areas, especially when the limestones and clays are exposed, while some of the areas of the Chester sandstones are of considerable size.

This region is badly cut up by the streams and consequently is very rugged and hilly with usually broad flat ridges. The soil of these broad ridges almost invariably rest on and is derived mainly from a sandstone of the Chester series. They are very fine grained and are very similar in character and give rise to soils of the same color and physical nature having the same togography, native growth, etc. In places the broad ridges lying within these sandstone areas are very flat and contain a number of square miles of territory. Such an area is found at Garfield and Hardinsburg and extending along the railroad between these two places. Many other level areas are found between the streams in different localities. These areas are usually flat, but not so large as to interfere with natural drainage.

These sandstones give rise to a rather uniform type of soil. The surface from 0″-6″ or 8″ varies from a gray to a light brown fine sandy loam. The soil is very loose, though it usually contains a very low content of organic matter and has a rather poor capacity for holding moisture.

The sub-soil is a yellow fine sandy material containing a fair per cent of clay. At a depth of from 24″ to 30″ it becomes quite plastic in places. The sandstones underlying these soils occur at a depth varying from 6 to 15 feet.

The hills and bluffs along the streams surrounding these flat areas afford the diversified soils. A single hill may have exposed two or more sandstones with an equal number of limestones alternating which of course give rise to very local soil areas. Usually because of being so small and because of occupying such an unfavorable topography these areas are of but little value from the standpoint of cultivation.

Even those soils that are derived from the limestone and clays receive so much sand from the alternating sandstones that the surface soil is very similar to the soils of the broad flat sandstone areas.

The surface from 0″ to 6″ or 8″ varies from a light yellow clay loam or loam to a light yellow fine sandy loam. The subsoil varies from a yellow clay to a yellow clay loam.

Following are physical analyses of Chester and St. Louis soils:

Physical Analyses of Soils from Chester and St. Louis Areas.

Field No.	Sample	1 2-1 m.m. per cent	2 1-.5 m.m. per cent	3 .5-.25 m.m. per cent	4 .25-.1 m.m. per cent	5 .1-.05 m.m. per cent	6 .05-.005 m.m. per cent	7 .005-.0 m.m. per cent	
25	Surface, Chester, 0-6″	.4	1.2	.7	2.9	13.7	61.48	15.3	
47	Surface, St. Louis, 0-6″	.0	.8	.6	2.8	13.86	64.06	16.6	
48	Sub-soil, 6-18″	.2	.5	.3	1.9	9.2	53.3	33.3	
71	Surface, Chester, 0-6″	1.5	2.5	.6	3.8	14.7	59.76	13.5	
72	Sub-soil, 6-18″	.6	1.5	.6	1.8	14.5	57.9	21.3	
26	Surface, St. Louis, 0.6″	.0	.7	.4	2.9	15.3	63.5	16.1	
27	Sub-soil, 6-18″	.2	.5	.2	1.3	12.4	62.7	24.5	
95	Surface, Chester, 0-6″	.4	1.2	.7	2.9	13.7	61.48	15.3	
0-6″ Chester									
	No. 95	.4	1.2	.7	2.9	13.7	61.48	15.3	
	No. 71	1.5	2.5	.6	3.8	14.7	59.76	13.5	
	Mean	.95	1.85	.65	3.35	14.2	60.62	14.4	96.02
0-6″ St. Louis									
	No. 47	.0	.8	.6	2.8	13.86	64.06	16.6	
	No. 26	.0	.7	.4	2.9	15.3	63.5	16.1	
	Mean	.0	.75	.5	2.85	14.58	63.78	16.35	98.81
6-18″ Chester									
	No. 72	.6	1.5	.6	1.8	14.5	57.9	21.3	98.20
6-18″ St. Louis									
	No. 48	.2	.5	.3	1.9	9.2	53.3	33.3	
	No. 27	.2	.5	.3	1.3	12.4	62.7	24.5	
	Mean	.2	.5	.25	1.6	10.8	58.0	28.9	100.25

The Chester and St. Louis surface soils are nearly the same in the mechanical analyses. The St. Louis subsoil, however, is more clayey than that of the Chester and both subsoils are more clayey than the top soils.

SOILS OF THE LIMESTONE AREA.

The St. Louis rocks form the predominating soil area in the limestone region. It is a fine grained limestone, containing considerable cherty material and has a total thickness of some five hundred feet. It is safe to say that the soils covering eight-tenths of the limestone area are formed from the St. Louis limestone.

The numerous depressions or sink holes in the St. Louis area give it a rolling topography, though in places there are large tracts of land that lie quite level.

The soils like those of all the uplands in this portion of the State are mainly residual. However, there are evidences of loess or transported materials in localities near the Ohio river. This is true in both the limestone and sandstone areas. In places Tertiary or recent gravel is found on the ridges near the river that underlie in some instances deep deposits of what resemble very much loess or wind blown soils.

The surface from 0″-6″ or 8″ of this St. Louis soil varies from yellowish or reddish loam to yellowish or reddish fine sandy loam. In places more or less chert is found, especially when the soils lie low down in the formation.

The subsoil is a reddish clay loam or loam usually becoming more clayey with depth. In places the surface soil is underlain with practically a bed of chert. The country along the railroad between Brandenburg and Irvington is in many places underlain with it. This material breaks up capillary action and consequently a very short drought checks the growth of crops.

The Keokuk area is of but little significance from the standpoint of soils since merely a narrow strip of the limestone is exposed along Otter creek from Garnetts-

ville to the mouth and also along Potter's Creek for a short distance.

The small coal measures area in the southwestern part of Breckinridge county contains soils very typical of the coal field. It is derived from loosely cemented coarse grained sandstone and varies from a yellow sandy loam to a sand. This area has a hilly topography.

There is but little bottom land along the small streams in these two counties. However, along the Ohio River there is some 10 or 12 square miles of alluvial soil. Like all river bottom soils they vary considerably in their nature. Near the river, sands and sandy loams are found while those near the hills or bluffs are loams and clay loams.

The native growth of the sandstone and limestone areas is very similar. Both areas contain vegetation characteristic of poor land. In these areas the red oak, black oak, white oak, post oak, hickory, persimmon, sassafras, and occasionally walnut, beech, poplar, and maple are found. On the flats in the Chester sandstone mainly the different varieties of oaks are found, while on the hillsides beech, maple and walnut are more often common.

TIMBER.

In Meade county there is only about 13,000 acres of timber or about 6½ per cent of the total area in the county, while in Breckenridge there is about 68,000 acres ir about 20 per cent of the total area. Of course in these areas the best timber has been cut and that which remains is an inferior grade.

CROPS.

Corn, wheat, tobacco, and hay are the principal crops grown in these counties. The average yield of corn per acre in Meade county in 1908 was 20.4 bushels; of wheat 9.3 bushels; tobacco 722 pounds, and hay .67 tons.

The average yield of corn per acre in Breckinridge

county for 1908 was 17.2 bushels; wheat 9.1 bushels; tobacco 721 pounds, and hay .56 tons. The yields point to the fact that either these soils are deficient in plant food or that very poor systems of farming are employed. The real gist of the matter is that both these facts are true.

The fact that the former is true is confirmed by a chemical analysis of the soils, which shows that they are extremely deficient in the elements nitrogen and phosphorus. But few soil areas are to be found with a lower content of these elements.

The fact that the latter is true, one may decide for himself if he will only observe and study the system of farming now employed in these two counties.

CHEMICAL ANALYSES OF THE SOILS.

So far the chemical analyses of the soils of these two counties are incomplete. The total phosphoric acid, total nitrogen and amount of lime required to neutralize the acidity by the Hopkins method, have been determined in 124 samples collected by the survey in 1907.

The total potassium which of course will furnish valuable information has not yet been determined in these samples. Again when work on the available plant food has been done further valuable information will be furnished. A study of the results that have been obtained points out many interesting facts concerning the soils of these two counties.

Altogether including both surface and subsoil, the phosphoric acid, nitrogen and lime requirements have been determined in 124 samples that were taken during the summer of 1907.

Of the 124 samples analyzed 32 were from the surface and 16 from the subsoil of the limestone area while 60 were from the surface and 16 from the subsoil of the sandstone or Chester area.

Below are given the analyses of those from the limestone area:

Surface O-6"				Sub-soil 6.—18"			
Sample No.	Acidity as CaO	Total P_2O_5	Total N.	Sample No.	CaO	P_2O_5	N.
1	.005	.101	.091	2	.084	.097	.050
3	.002	.100	.155	4	.034	.085	.055
5	.002	.093	.085				
6	.004	.077	.057				
7	.001	.154	.122	8	(Alk.) .0022	.121	.074
9	.002	.094	.090	10	.501	.068	.041
11	.002.	.085	.075	22	.013	.073	.055
12	.007	.093	.085				
13	.013	.068	.070				
14	.002	.115	.127	15	.001	.094	.077
16	.002	.116	.106				
17	.002	.078	.096	18.	.091	.070	.038
19	(Alk.) .0123	.070	.062				
20.	.001	.101	.106				
21	.003	.101	.106	22	.013	.073	.055
23	.000	.251	.208				
24	.002	.051	.085				
25	.030	.073	.065				
26	.001	.083	.073	27	.037	.061	.041
28	.002	.061	.082	29	.532	.048	.041
30	.042	.060	.078				
31	.051	.055	.060	32	.161	.053	.040
42	.002	.070	.086	43	.041	.055	.049
44	.003	.055	.078	45	.501	.040	.032
46	.008	.087	.102				
47	.002	.051	.093	48	.073	.042	.036
49	.002	.086	.095	50	.021	.073	.046
51	(Alk.) .0038	.065	.078				
52	.032	.070	.042	53	.223	.051	.019
60	.002	.086	.079	.61	.223	.051	.019
62	.014	.083	.092				
79	.002	.080	.095		2.310	.995	.699
	.303	2.823	2.593	Av'ge	.154	.063	.047
Av'ge	.0104	.0882	.086				

Below are given the analyses of those from the sandstone area:

Surface				Sub-soil			
Sample No.	CaO	P_2O_5	N.	Sample No.	CaO	P_2O_5	N.
33	.001	.055	.070	34	.013	.071	.044
35	.001	.086	.134				
36	(Alk.) .0067	.084	.086	37	.024	.063	.044
39	.002	.064	.073				
54	.011	.055	.083	55	.168	.053	.035
56	.003	.068	.097				
57	.002	.066	.062				
58	.003	.078	.094				
59	.010	.088	.086				
63	.003	.083	.076				
64	.006	.083	.100	65	.083	.061	.132
66	.003	.074	.119				
67	.006	.049	.093				
68	.001	.048	.099				
69	.017	.066	.095				
70	.092	.061	.086				
71	.001	.085	.075	72	.130	.068	.039
73	.003	.090	.121	74	.076	.080	.064
75	.016	.073	.079				
76	.047	.063	.073				
77	.004	.065	.117				
78	.002	.088	.134				
80	.002	.080	.095				
81	.003	.078	.104				
82	.001	.081	.081				
83	.002	.096	.097	84	.002	.080	.074
85	.002	.025	.107				
86	.001	.103	.125				
87	.001	.031	.093	88	.002	.064	.045
89	.001	.080	.098	90	.002	.069	.058
91	.003	.089	.073				
92	.045	.080	.111				
93	.001	.080	.102	94	.053	.066	.046
95	.003	.083	.101	96	.035	.065	.057
97	.004	.070	.070				
98	.001	.073	.077				
99	.003	.079	.123				
100	.003	.089	.117	101	.006	.060	.057
102	.002	.060	.112				

Surface				Sub-soil			
Sample No.	CaO	P_2O_5	N.	Sample No.	CaO	P_2O_5	N.
103	.003	.073	.095				
104	.011	.059	.070				
105	.003	.074	.087				
106	.003	.089	.112				
107	.001	.080	.114				
108	.001	.065	.099	109	.034	.054	.053
110	.002	.049	.111				
111	.003	.070	.082				
112	.001	.096	.092				
113	.031	.059	.068				
114	.002	.065	.105				
115	.002	.072	.079	116	.063	.067	.049
117	.003	.102	.111				
118	.003	.100	.114				
119	.015	.074	.091				
120	.003	.071	.084	122	.009	.066	.060
123	.003	.065	.098				
124	.003	.063	.103				
125	.000	.103	.098				
127	.001	.084	.140	128	.002	.086	.093
	.339	4.454	5.780		.702	1.073	.950
Av'ge	.006	0.742	.096	Av'ge	.044	.067	.059

It will be seen that the different samples of soils from both areas vary considerably in the percentages of phosphoric acid and nitrogen they contain and also in the amount of lime required to neutralize the acid.

The total averages of the many samples analyzed from the surface and subsoil of these two areas bring out many interesting points as are indicated below.

Surface, First 6".

	Acidity as CaO	Total P_2O_5	Total N.
Limestone soil	.0104	.0882	.086
Sandstone soil	.106	.0742	.096

Sub-soil.

	Acidity as CaO	Total P_2O_5	Total N.
Limestone soil	.154	.066	.047
Sandstone soil	.044	.067	.058

Over an acre to a depth of seven inches there is approximately two million pounds of soil. Figuring on this basis it would require 208 pounds of lime to neutralize the acid contained in the surface of the St. Louis or limestone soil, while for the same amount of subsoil it would require 3,080 pounds. The surface of the Chester or sandstone soil would require only 12 pounds of lime to neutralize the acid, while the same amount of subsoil would require 880 pounds. Figuring the phosphorus and nitrogen to the element on this basis the surface of the St. Louis contains 758 pounds of phosphorus and the subsoil 567, while the surface of the Chester contains 638 pounds and the subsoil 576. The surface of the St. Louis soil contains 1,620 pounds of nitrogen and the subsoil 940, while the surface of the Chester soil contains 1,920 and the subsoil 1,160 pounds. It is rather difficult to account for the fact that the soil derived from the limestone is more acid than that derived from the sandstone. Also that the subsoil should be more acid than the surface.

The fact that the limestone soil is derived from rocks so largely of animal origin may account for it being richer in phosphorus than the sandstone. Again why is the subsoil of the Chester or sandstone area as rich in phosphorus as that of the St. Louis or limestone area? The phosphorus is no doubt largely contained in the finer particles of a soil. The Chester soils being more sandy and porous than the St. Louis or limestone soils, a larger proportion of the finer particles have been carried down into the subsoil.

The fact that the limestone area is more susceptible to erosion, that is, that it undergoes more of a mechanical loss by soil washing than the sandstone area, especially that portion of the sandstone area from which the samples were taken, may account for the soil containing less nitrogen than the soil of the sandstone area.

POT CULTURE EXPERIMENTS.

For pot culture experiments soils were collected from the Chester and St. Louis areas in Breckinridge county in August 1909.

The soil from the sandstone area was taken from a field about ½ mile south of Garfield. It lies in the Garfield sandstone and is typical of the sandstone area. The field was in corn and would apparently yield only about 15 bushels per acre, This land has been under cultivation for many years.

A chemical study of this particular soil reveals the following facts: Figuring on the basis of two million pounds of soil to an acre it requires only 80 pounds of lime to neutralize the acid present. This amount of soil contains 1,600 pounds of total nitrogen, 24,734 pounds of total potassium and 752 pounds of total phosphorus. A fifth-normal nitric acid solution shows 226 pounds of available potassium and only 12.4 pounds of available phosphorus.

In both the Chester and St. Louis soils two series of pot culture experiments were carried on. In each series 4-gallon pots were employed and 15,000 grams of soil used in each pot.

On November 5, 1909, one series of each was planted in clover and the other in oats.

The following amounts of materials per pot were used to supply plant food:

To supply nitrogen 6.5 grams of dried blood were used. It contained 12 per cent of nitrogen. To supply lime 15 grams of ground Bowling Green limestone, containing about 98 per cent of calcium carbonate; to supply phosphorus 3.8 grams of precipitated bone phosphorus, containing 15 per cent. P. or 20 grams of Tennessee rock phosphate, and to supply potassium 3.2 grams of potassium sulphate were used. Where manure was supplied 35 grams of dry bone dung were used, containing 1.51% N. .78% P. and 1.83% K.

The first crop of clover was harvested from each series April 25, 1910, and the second June 6, 1910. The series containing the oats were also harvested June 6th. The crops were weighed after air-drying.

The following tabulations contain the results from the Chester series.

Clover.

Pot No.	Treatment	Wt. of first cutting	Gain	Wt. of second cutting	Gain
334	None	15.2	....	10.9	....
335	Ca Co_3	14.8	.4	12.1	1.2
336	N	18.0	3.3	12.4	1.5
337	P	25.3	10.1	18.1	7.2
338	P+Ca Co_3	33.0	17.8	20.2	9.3
339	K	23.2	8.0	13.9	3.0
340	Rock phosphate	30.8	15.6	19.6	8.7
341	Manure	33.4	18.2	2.1	11.2
342	Manure+rock phosphate	30.8	15.6	25.6	14.7

Pot No.	Treatment	Whole crop Gr. per pot	Increase Gr. per pot	Oats Gr. per pot	Increase Gr. per pot
311	None	38.2	....	4.3	....
312	None	38.7	....	6.5	....
313	N	46.0	7.55	9.5	4.1
314	P	38.3	.15	4.5	.9
315	K	46.6	8.15	5.4	0.6
316	N P	62.0	23.55	14.1	8.7
317	N K	67.8	29.35	11.0	5.6
318	P K	46.0	7.55	4.8	—0.6
319	N P K	82.2	43.75	10.6	5.2
320	Rock phosphate	40.6	2.15	4.7	—0.7
321	Manure	33.9	—4.55	5.0	—0.4
322	Manure and rock phosphate	37.0	—1.45	10.8	5.4

ST. LOUIS SOIL.

The soil from the St. Louis area was taken from the farm of W. G. Bandy, 1-4 mile west of Irvington and 10 rods north of L. H. & St. L. R. R. This land has been under cultivation 19 years, but has had rest one-third of the time. Fertilizers have been used only two years. The area from which the soil was taken lies near the top

of the St. Louis limestone. Figuring on the basis as given above this soil requires only 20 pounds of lime to neutralize the acid contained in an acre of 7 inches. In an acre there is 1,940 pounds of total nitrogen, 31,042 pounds of total potassium and 645 pounds of total phosphorus. The fifth normal acid solution shows 425 pounds of available potassium and 13.7 pounds of phosphorus.

The following tabulations contain the results obtained from the pot culture experiments with the limestone soil.

Clover.

Pot No.	Treatment	Wt. of first cutting	Gain	Wt. of second cutting	Gain
343	None	26.7	....	18.7	....
344	Ca Co,	18.0	—8.7	14.0	—4.7
345	N	22.6	—4.1	15.0	—3.7
346	P	30.1	3.4	22.8	4.1
347	P+Ca Co,	60.7	34.0	40.6	21.9
348	K	26.0	.7	16.3	2.4
349	Rock phosphate	25.0	8.3	25.1	6.4
350	Manure	38.3	11.6	21.5	2.8
351	Manure and rock phosphate	48.5	21.8	32.2	13.5

Pot No.	Treatment	Whole crop Gr. per pot	Increase Gr. per pot	Grain Gr. per pot	Increase Gr. per pot
323	None	60.0	....	10.5	....
324	N	73.0	13.0	10.6	0.1
325	P	72.5	12.5	9.9	—0.6
326	K	71.5	11.5	9.4	—1.1
327	N P	121.3	61.3	16.9	6.4
328	N K	84.2	24.2	17.0	6.5
329	P K	70.4	10.4	11.0	0.5
330	N P K	150.0	45.0	24.4	13.9
331	Rock phosphate	72.3	12.3	12.8	2.3
332	Manure	70.0	10.0	9.8	—0.7
333	Rock phosphate+manure	63.4	3.4	10.5	— .0

In the first cutting of clover in the Chester soil ground limestone gave a decrease, while it gave an increase in the second cutting. It shows a decrease in both cuttings in the St. Louis or limestone soil.

The nitrogen pots show an increase in both cuttings in the Chester soil, while it shows a decrease in both cuttings of the St. Louis soil. The St. Louis soil contains 340 pounds more nitrogen to an acre than the Chester. In both series with oats nitrogen gives an increase.

Phosphorus in every combination where clover was grown shows a very marked increase, while where oats were grown it shows a decrease in several instances.

In the clover series potassium shows an increase with the exception of the first cutting in the St. Louis soil. It also shows a decrease in the yield of oats in the St. Louis soil and no increase in the Chester. In the oats series all combinations of the elements give an increase except in the yield of grain in the Chester phosphorus and potassium combined show a slight decrease.

In the clover series in every instance manure gives an increase, while it shows a decrease in several instances in the oats.

AGRICULTURAL CONDITIONS AND SUGGESTIONS FOR IMPROVING THEM.

In many instances farmers try to cultivate too much area, which of course means that the seed bed is not properly prepared before seeding and after seeding too little cultivation and care is given to such crops as corn and tobacco, especially corn. For instance the writer was told of a farmer in Meade county who was trying to cultivate seventy-five acres of corn with facilities and labor for about twenty-five acres. Now what does this mean? It means rapid land ruin and no profit to the operator of such a farm, because when land is poorly cultivated it washes much more than when well cultivated, and the profit is much less because of the low yield per acre and the comparatively larger amount of capital involved in the larger area.

Again very poor systems of rotation are practiced, in fact with many farmers no system is practiced, but the land is cultivated over and over again in the same crops, or rotated with wild crops of Japanese clover and weeds.

The writer found objections to growing stock peas and beans in a rotation on the hill land. The reason given was that these crops leave the soil so loose that it washes badly through the fall and winter after they have been harvested. It did not seem to occur to them that some sort of small grain such as rye should be sown immediately after harvesting the peas or beans. This would hold the soil together and fix in organic form much of the nitrates that would otherwise be lost in the drainage waters, and at the same time would add vegetable matter to the soil which in this area is so badly needed.

There is a great lack of knowledge on the part of the farmer in regard to purchasing and supplying plant food to either soils. The writer found a farmer in Meade county in the Chester area who had added 100 barrels of lime to the acre and 400 pounds of low grade commercial fertilizer. His lime (purchased from a kiln near home) cost 15 cents per barrel or $15 per acre and for the 400 pounds of fertilizer he paid about $5, making a total of about $20 per acre, which was in fact almost as much as the value of the land. Even at this exorbitant cost he claims to have realized a fair profit on the money invested. He was practicing a system of rotation in which clover was being grown and fed and the manure returned to the land. With a knowledge of the plant food content of his soil, of how plants feed and of the elements taken from the soil, and the cheapest forms in which they can be added he could no doubt obtain as good results with one-third the cost. The instance cited above is an exception rather than a rule. In these counties so far lime is not much used and only about 100 pounds of low grade fertilizer is supplied to an acre and clover is often a failure even when sown.

A crop of corn producing fifty bushels removes from an acre 35 pounds of potassium, 11.5 pounds of phos-

phorus and 75 pounds of nitrogen. One hundred pounds of the fertilizer used by the farmer referred to above would supply to an acre 3.6 pounds of potassium, 3.87 pounds of phosphorus and 0.41 pounds of nitrogen. It would naturally be inferred that the effect would not be very marked.

A study of the chemical analysis of these soils given above, shows them to be rich in total potassium and poor in total nitrogen and phosphorus.

How is the large store of potassium to be made available in these soils and how is phosphorus and nitrogen to be added?

By growing clover and other legumes nitrogen can be added to a soil from the larger store in the atmosphere.

The application of rock phosphate in the pot culture experiments with clover in both the Chester and St. Louis soils shows in every instance very marked results, in one more than one hundred per cent. increase. It is no doubt true that all legumes possess a similar power of laying hold of inert materials such as rock phosphate. Then to build up these soils legumes should be grown and large quantities (say 1,000 pounds per acre) of rock phosphate should be added when the soil is being prepared for the seeding of legumes. The legumes may be turned under directly or fed as hay and the manure returned to the soil. The latter, however, is considered more profitable. In this way large quantities of organic matter will be supplied which will give rise to organic acids. These acids will act upon the inert mineral content in the soil, and liberate potassium and phosphorus.

Though these soils are only slightly acid, in all probability light applications of some form of lime would be beneficial with legumes, especially if any acid form of phosphorus is used.

There are large quantities of rather pure limestone in these counties that no doubt could be turned into profit for the operator and farmers as well, if a plant for making ground limestone were introduced. In the long run ground limestone proves to be more profitable for acid

soils than quick or burned lime. The quick limes serve as a stimulant and depletes a soil of vegetable matter.

More precautions should be taken to prevent soil washing. This may be profitably done by expending money and energy in utilizing the waste materials as manure, old straw piles, etc., in helping to get grass on the barren hills. More grass would enable the farmers to keep more live stock. At present, including horses, mules, cattle, sheep and hogs, there is only one animal for each seven acres.

The following papers on The Manufacture of Coke, by William Hutton Blauvelt, of Syracuse, N. Y., and F. E. Lucas, of Sydney, N. S., were originally read before the American Institute of Mining Engineers in October, 1912.

In view of the rapid development of the coking industry in Kentucky they are of great interest to the operators in this State and are reproduced here by special permission of the Secretary and Editor of the Bulletin of Transactions of the Institute.

THE MANUFACTURE OF COKE.*

BY WILLIAM HUTTON BLAUVELT, SYRACUSE, N. Y.

(Cleveland Meeting, October, 1912.)

Coke is the production of dry distillation of bituminous coal, by which the volatile matter is driven off, producing a hard body of cellular structure. Not all bituminous coals will coke, and there has been much discussion regarding the substance which is present in coking-coals to distinguish them from dry coals. Professor Lewes says that the bituminous matter in coal is largely derived from the spores of fossil mosses. Resins are present in all soft coals, and contribute largely to the cementing of the coke. The resinates and hydrocarbons begin to distil out at moderate temperatures and leave the pitchy residual, which at 500° C. forms a mass already well caked together, if the proportion of humus residual is not too great. This coke is soft, but if the heat be raised to 1,000° C. the pitch decomposes further, leaving carbon, and Professor Lewes is convinced that the coking bond is due to these liquid products which distil off, leaving pitch, which then carbonizes and binds the mass into coke.

Professor Parr concludes that the structures of the organic compounds of the coal which furnish the cementing-material for coke, and which are apparently attacked by oxygen, have not been determined and seem to vary somewhat in different types of coal. However, they yield, on oxidation, humic acids of varying composition which decompose into powdery residues. Because of the complex nature of these substances and the difficulty experienced in isolating and identifying them, the theory of coking is still an open problem and the explanations advanced are largely hypothetical.

In the coking process the volatile matter driven off in the oven consists mainly of tar, ammonia, and gas, familiarly known as by-products. Both the quality and quantity of coke and by-products vary greatly with the

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composition of the coal. In America, coals similar to those of the Pocahontas region, containing as low as 16 per cent, or less of volatile matter, stand at one end of the list. In Europe, some coals are coked which contain not more than 13 per cent of volatile amtter. These produce the maximum yield of coke and the minimum yield of by-products. At the other end of the list are the gas-coals, containing as much as 38 or 40 per cent of volatile matter, and yielding correspondingly small amounts of coke. The development of the best cell structure is of the highest importance in the production of metallurgical coke. A well-developed cellular structure presents a large surface to oxidation by air, producing rapid combustion, while the strong cell-wall prevents crushing and maintains an open fuel-bed. A soft thick cell-wall is objectionable in blast-furnace coke, since it permits the oxidizing action of CO_2 gases in the upper part of the furnace, by which the coke is wasted and the furnace-top temperature is increased. In foundry work it is more desirable to have a coke with a softer cell-wall, smaller cell space, and a strong, tough structure. This permits the air to burn the coke immediately to carbon dioxide, with production of the highest temperature in the melting zone of the cupola, and the weight of the charge is easily supported. Thus present practice seems to indicate that somewhat different treatments are required for producing furnace and foundry coke.

Coals high in oxygen are usually deficient in coking-qualities, and either will not coke at all, or produce a coke of weak, friable structure. But many coals, as will be shown later, which yield poor coke under ordinary conditions, may, by proper treatment, be made to produce good metallurgical coke. Coal when stored absorbs oxygen, sometimes with serious effect on its coking-qualities. The chief reason for this appears to be the effect of the oxygen on the resinates, which Professor Lewes says are thereby converted into humus.

The history of coke making has been discussed at length in the technical publications, by me[1] and others, and any reference to it here would be unnecessary repetition. The same statement applies to the earlier forms of bee-hive and by-product ovens, and the development from these earlier forms to modern types. The term by-

product oven is commonly applied in this country to the retort oven, although, of course, the by-products may or may not be recovered from the gases from retort ovens, depending upon market conditions. All the retort oven-plants in the United Statts have by-product recovery-apparatus. In this paper, the term by-product oven will often be employed, as being a more familiar term, in referring to the retort oven.

For many years the bee-hive oven was the standard for coke making, and has remained the standard in England and America long after its practical disappearance from continental Europe. There are several reasons for this. In England, the Durham coal, and in America, the Connellsville coal, are remarkably well-suited to the conditions of the bee-hive oven, so that the best quality of coke could be produced without difficulty, and with relatively good economy. In America, the bee-hive oven had certain economic advantages. It is quickly built, and at relatively low cost, and the labor required for operation is of low grade. It can be put out of run at relatively small loss during periods of industrial depression, and can be started up again with ease after a shutdown. These qualities adapted it to the fluctuating and changing conditions which for many years surrounded our iron industry. But the iron industry has become more stable; and moreover, the coals best adapted to the bee-hive oven are growing scarcer, especially with the exhaustion of the Connellsville field. The U. S. Geological Survey reports that in 1911 the total coke production in the United States showed a decrease of about 15 per cent while the output of by-product coke increased 10 per cent. Compared with five years ago the following are the figures of production:

	By-Product.	Bee-Hive.
1907	5,607,899	35,171,655
1911	7,847,845	27,207,517

This shows an increase in by-product coke of 40 per cent, and a decrease in bee-hive coke of 22 per cent, so that in 1911 the tonnage of by-product coke was 28 per cent of the bee-hive tonnage. By-product plants now under construction and in contemplation will greatly in-

crease the present output. In England the relative growth of the by-product oven has been even more rapid during the last few years.

The generic differences between the structure of the bee-hive and by-product or retort oven need not be again described here. It is sufficient to say that the bee-hive process consists essentially in the heating of the coal with controlled admission of air to the coking-chamber, so that the heat necessary for the distillation of the volatile matter is produced by combustion within the oven-chamber. In the by-product oven the process is a true dry distillation. No air is admitted to the chamber, and the heat necessary for the distillation is supplied through the chamber walls.

The bee-hive oven has been carrier to its highest perfection in this country; drawing- and loading-apparatus has been applied to it, to reduce the arduous labor of the old hand-method; and modifications of the original bee-hive shape have been successfully introduced, which add materially to the economy of operation, while maintaining the principles of carbonization as employed in the standard bee-hive.

The bee-hive oven is usually located at the coal-mine, and the coal is in very many cases charged direct to the oven without weighing, so that it is difficult to ascertain the exact yield of the oven; but except when coals are used which are especially adapted to the bee-hive process, the coke yields are considerably below the theoretical, and, of course, all the by-products are wasted. These facts, except in unusual cases, make it impracticable to locate bee-hive ovens away from the mines. On the other hand, the by-product oven is usually, in this country at least, located at the point of consumption of the coke, or at some center of distribution. This freedom of location of the by-product oven has a number of advantages. Although it entails charges on from 1.2 to 1.4 tons of coal for every ton of coke produced, yet coal usually carries a lower rate than coke, and is more easily transported, not requiring special cars and not being injured by handling. In some cases it can be shipped by water, with material saving in freights, and with proper care it can be stored at the plant in almost any quantity without material deterioration. This permits a blast-furnace

plant, having its own coke-ovens at the furnace, to possess an assured supply of coke, independent of weather or shipping-conditions. It is quite common for by-product oven-plants to accumulate a stock of from one to eight months' supply of coal. The by-products produced are much nearer their market, and the gas is often available for industrial uses or for municipal lighting. The plant is nearer a supply of diversified labor, which is an advantage in the more varied processes of by-product oven-operation. An important advantage of locating the oven-plant at the point of consumption is, that it permits a convenient assembling of several kinds of coal at the ovens. This mixture of coals is often a great advantage, since it permits the best quality of coke to be produced, when the coke made from any one of the coals alone might be of inferior quality, or perhaps not at all adapted to the market requirements.

There has been much discussion regarding the relative cost of bee-hive and by-product oven-plants. It is difficult to make an exact comparison, since the functions of the two types are quite different. For example, in many cases the cost of a by-product oven-plant includes a large expenditure for coal-storage of several hundred thousand tons, in order to take advantage of water freight-rates. On the other hand, bee-hive plants are often built in connection with coal-mining plants and utilize a share of power-plant, water supply, etc., without having these necessary adjuncts included in their capital account. Careful inquiry into the actual cost of bee-hive oven-plants shows that to build such a plant complete in every respect, and in the best manner, including all the equipment besides the ovens and their immediate appurtenances, such as electric power-plant, water-supply, railroad-approaches and sidings, coal-handling, etc., would require an expenditure of about $950 per oven. The U. S. Geological Survey report for 1911 gives the tonnage of coke produced per active bee-hive oven at 466 tons per annum. This figure is doubtless low for the best bee-hive ovens; 675 to 700 tons per annum will perhaps represent fairly the average output per oven of a modern bee-hive plant. An average of these figures gives a plant-cost of $1.38 per ton of coke produced per annum. A by-product oven-plant of, say, 80 ovens, complete in

every respect, and built in the best manner, would produce, say, 425,000 tons of coke per annum from an average coal, and would cost, say, $1,100,000. Of course, this figure would be varied by local conditions. This is equal to $2.58 per ton of coke per annum. On the basis of these figures a by-product plant costs 86 per cent more than a bee-hive plant.

The owner of a small acreage of coking-coal might perhaps well hesitate before making the larger investment, as compared with a simple plant of bee-hive ovens, but, as a general proposition, there hardly seems to be a question as to which style of oven is the better investment. Much of the additional cost of the by-product plant per unit of coke produced is, of course, due to the installation of the apparatus and buildings for the recovery and treatment of the by-products. Other important items are provisions for coal and coke-storage, thereby assuring uniformity of operation and greater ability to maintain uniform deliveries. Moreover, a by-product plant is built for a longer life than a bee-hive plant. Eight years may perhaps be considered as a satisfactory life for a bee-hive oven-plant, while double this term. or 16 years, would be several years within the life of a well-built by-product plant.

Market conditions have not been such in this country as to justify construction of retort oven-plants without the recovery of by-products, but we may assume a non-recovery oven-plant built for operation in the Pocahontas region, for example. The yield of coke from Pocahontas coal averages certainly not more than 60 per cent in a bee-hive oven. In a retort oven the yield is more than 80 per cent. Such a plant without by-product recovery costs not much more per ton of product than an equally well equipped bee-hive plant, and the labor of operation under such conditions would be as low, if not lower. A plant of retort ovens in place of bee-hives in that field would, therefore, mean that at practically the same expenditure the owner of a coal property would, on account of the greater yield of coke, increase the life of his coal-field 33 per cent with a given output of coke. Or the value of the property, based on the selling-value of the coke therefrom, would be increased 33 per cent.

The present development of the art, however, has brought the Pocahontas coal to the ovens located at the point of consumption, and the mixing of low and high volatile coals has grown in favor, especially during the last few years.

The cycle of operations in connection with the by-product oven has been described several times in technical papers, and need not be repeated here. It is well recognized that the operation of these plants calls for technical skill of high order, as the several processes include metallurgical, mechanical, and chemical engineering, and the success and economy of the operation are largely dependent upon the accurate control of a number of quite different and independent conditions. There has been great progress in the design of the ovens and recovery-apparatus. As might be expected, America now leads Europe in output of plant, size of oven, and rate of coking. In the early days of the by-product oven in America, the capacity of the oven was about 4.4 tons of coal per 24 hr., and 25 ovens were considered about the right number for one crew of men. Modern ovens have a capacity of as much as 20 tons of coal per oven per day, and by the introduction of more machinery and more efficient design, the number of ovens handled per man is also increased greatly. The rate of coking is one point in which American practice has gone ahead of Europe.

Retort ovens have been built of various widths from about 14 to about 30 in., to suit various ideas of the designers, and various coals; but, within limits, the rate of coking per inch of coal does not vary materially with the width of the oven. Not many years ago the best rate of coking was about 1 in. of oven width in 90 min.; that is, a 16-in. oven was coked in 24 hr. Today there is more than one type of oven which is coking regularly at the rate of from 50 to 55 min. per inch of oven width. This increased rate was made possible, partly by better control of the heating-systems, and partly by the adoption of silica brick in the oven construction. Silica brick has been used in bee-hive oven construction very generally for a number of years. In retort ovens it was first used in the Otto-Hoffmann oven-plant at Johnston in 1899, and is now the standard material in America for retort-oven construction.

During the past few years special study has been given to the heat economy of the retort oven and material advance has been made. From most American coals, more gas is produced than is necessary for heating the ovens. The conditions under which it is to be operated have an important bearing on the design of an oven-plant. It may be said that there are three general conditions. First, where there is not sufficient market to dispose of the surplus gas. In this case the design of oven should be very simple. Any complication of the design for preheating the air should be avoided, since satisfactory coking-temperatures can be maintained with cold air, if economy of gas is no object. Steam for the operation of the plant should be raised by burning the surplus gas under simple boilers. This simplicity of design permits material economy in cost of construction and maintenance, and also reduces the cost of operation.

In the third case the gas is salable at a good price, so the gas, perhaps for industrial purposes, but at a low price, and the cost of coal and labor is relatively high. In this case the oven-design should provide for partial heating of the air, with proportionate economy of gas for heating the oven, so that the remaining heat in the waste gases is just about sufficient to furnish the steam required for the plant. This design gives an oven of moderate cost for construction and upkeep; the operation of the boiler-plant is reduced to its lowest terms, with minimum of labor and repairs; and at the same time a very considerable percentage of the total gas produced is available for sale.

In the third case the gas is salable at a good price, so that it is desirable to recover the maximum amount for sale. Under these conditions an oven-design is justifiable which, while more costly in construction, is most economical in heat-consumption. The air is heated in the best form of recuperators or regenerators to 1,000° or 1,100° C., and the waste gases go to the chimney too cool to be of value. Under these conditions coal and coke-breeze are used for producing the necessary steam Whether steam is used for the production of power, as well as for the distillation of ammonia, heating, etc., or whether the power is generated by gas-engines, depends upon the relative market value of coal and gas. A proper

recognition of the conditions of installation, and the adaptation of the design to them, is an important factor in the most economical installation of a retort oven-plant. It is by no means always the case that the most highly efficient heat-economy within the oven itself is most economical for the plant, and very good results can be obtained in some cases without the most expensive oven-construction. The average of a year's results from two plants which have come within my knowledge, using coal containing less than 27 per cent volatile, showed more than 4,200 ft. of gas sold per ton of coal coked for the entire year. Statements regarding volumes of gas recovered are often misleading, since the quality may vary greatly: so it may be of more interest to say that the heat-units in this gas averaged from the two plants for the entire year well over 2,600,000 B. t. u. per ton of coal coked, or about 44 per cent of the heat in the total gas. While these figures can be materially improved by more expensive construction to effect greater heat-economy in the oven, the above results were obtained with the simplest form of apparatus for preheating the air, and at the same time all the steam required for operating the plant, handling and storing coal, distilling ammonia, etc., was produced from the waste heat, assisted by the breeze produced at the plant.

The following tabulated data show in a general way what may be expected from plants designed for the three conditions mentioned above. The figures show the results per ton of coal coked. They represent average conditions and average coals, and, of course, would be modified by special conditions.

Type of Oven.	Fuel Gas. Per Cent.	Surplus Gas. Per Cent.	Steam produced. Pounds.
No air preheating	70	30	1,050
Partial air preheating	60	40	800
Maximum air preheating	40	60	0

The tendency of modern retort-construction, especially in America, is towards the highest economy of heat, even at the expense of simplicity and economy of construction. The proper heating of a retort oven is not a simple problem. It consists essentially in the distribution of heat from burning gases over the side wall of the

oven, which presents an area from 35 to 40 ft. long, and from 8 to 12 ft. high. The temperature over this entire area must be always under accurate control. When operating for maximum output the temperatures must be held at a point not far below the softening-point of the brick; and since the oven-chamber is wider at one end than at the other, to permit easy discharge of the coke, the heats must be modified accordingly, so that the whole charge may be coked in the same time. It is also often desirable to maintain a somewhat lower temperature in the upper part of the oven. The combustion of the gas with air which has been preheated to, say, 1,100° C., as it is in the latest regenerator ovens, produces a theoretical flame-temperature of about 2,400° C. The actual temperature produced would be much above the melting-point of the best refractory brick, and while economical operation demands a full utilization of the best temperatures attainable, the walls of the combustion flues must not be injured, nor must there be "hot-spots" or "white ends" that will overburn the coke in the adjacent part of the oven-chamber.

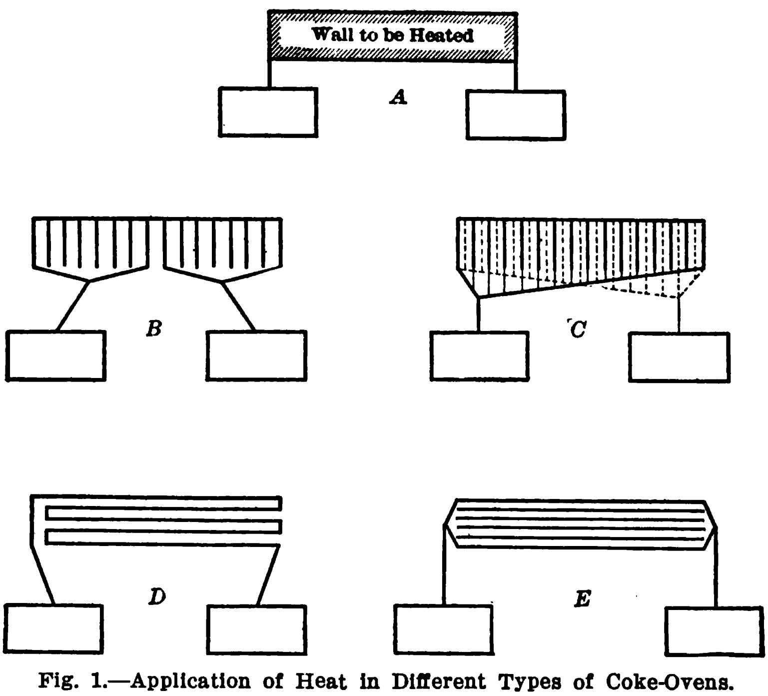

Fig. 1.—Application of Heat in Different Types of Coke-Ovens.

*Fig. 1 shows diagrammatically the application of the heat in the different types of ovens. *A* indicates the combustion-flue system of any retort oven with its regenerative chambers below. *B* and *C* show applications of this general arrangement as adopted by oven-system employing vertical flues. *D* shows the application to the horizontal-flue ovens of the series type. *E* a horizontal type where all the flues are in parallel. *B*. *C*, and *D* represent the methods generally adopted in commercial ovens. In the former type, or the vertical-flue oven, the gas and air are mingled and burned in horizontal flues at the bottom of the vertical flues, the burning gases distributing themselves and passing up one-half the vertical flues and down the other half, as indicated in the sketch; or gas and air are led separately to the bottom of each of the vertical flues, where they are mingled by properly arranged nozzles and burned as they pass upward. In some ovens a combination of these methods is adopted. *D* illustrates the horizontal series-flue regenerator oven; and, as I have had more experience with this type, it may be of interest to discuss somewhat in detail the principles of its operation. All of the air required for the combustion is passed through the entire flue-system, first from above downward, and then from below upward, as the regenerator system is reversed. The heating gas is admitted at the end of the flues, usually in four or five places, as may be required. This method seems to give a maximum if simplicity. The flow of gas is automatically reversed in the flues themselves by the change in the current of air. Every flue may be convenintly inspected from end to end by a man walking along in front of the ovens, and the gas-admission at each point is directly under his hand, so that there is no excuse for failure to immediately observe and correct any tendency to unequal heating. The distribution of the heat throughout the flue-system is made remarkably uniform by this process. This is partly due to the comparatively high velocity of the gases sweeping through the flues, and to the fact that the gas is burned either in a large excess of highly-heated air, or else in a mixture of air and products of combustion. The advantages of the presence of products of combustion in the combustion-chamber, where it is desired to obtain a distribution of heat, have

been clearly shown in other combustion processes, such as the Doherty system of producer operation, for example.

In beginning the experimental work leading up to the present method of operation, while it was recognized that the presence of a large volume of air, together with products of combustion mixed with the burning gas, was an important factor in distributing the heat with uniformity, yet it was feared that passing the entire volume of air through all the flue-system might seriously increase the friction and make the maintenance of sufficient draft a difficult matter, even though the total amount of air admitted could be accurately proportioned so that it would be just sufficient to burn all the gas. Hence, an oven was designed with the flues in parallel, in order to reduce the velocity of the gas-currents, following the principle of the vertical-flue type. It was found, however, that the velocity of the gases passing through the flues did not produce material friction-loss, but that most of the friction arose from eddies in the currents at the ends of the flues; and by a suitable modification of the structure at these points it was easy to keep down the draft required to a reasonable amount, while maintaining the velocity of flow that was so effective in securing uniform heats. This method of handling the gases through the flues in these series-flue ovens has, therefore, two advantages. It is effective in distributing the heat uniformly from one end of the flue to the other, and at the same time the higher velocities effect a more efficient transfer of heat through the flue-wall. The effect of velocity of travel on the transfer of heat through walls has also been shown very clearly in a series of experiments on steam-boilers made by the Engineering Experiment Station of the University of Illinois.* It will be remembered that these tests were undertaken to determine the relation of heat-transmission to velocity of circulation in the steam-boiler. They show very clearly the important effect of velocity flow on rate of heat-transmission, and from the deduction therein set forth it would appear that the same conclusions may be drawn in the study of our problem. Having obtained by these

*Bulletin No. 40, University of Illinois (1909).

means such an effective distribution of the heat, the arrangement of gas-admission to the flue-system makes it easy to control the temperature of the whole system under the severe conditions described above. The result is that in this type of oven the heat is remarkably uniform from end to end, hot or cold spots are practically unknown, and the control of the temperature is much easier than ever before.

The temperatures maintained in the flue-system, depend, of course, upon the rate of coking it is desired to maintain. They usually run from 1,000° to 1,250° C., or somewhat higher. The temperature at the point of entrance of the heated air is controlled by the admission of the proper supply of gas, and additional gas is introduced at other points in the system in order to make up for the heat transmitted into the oven-chamber, or to augment the temperatures as may be necessary in preserving the proper relations of heat in the different parts of the system. The periodical reversal of the gas-currents prevents any tendency to inequalities which might otherwise develop.

The perfecting of this system makes the regenerative retort oven quite as simple and easy to operate as the recuperative oven, and at the same time secures the maximum heat-economy. There is only one reversing-valve on each oven-block, by which the currents of air and products of combustion are reversed through the system; and this may be easily operated by a simple mechanical device with time-control. All the other advantages of the older system, of simplicity and reliability of operation, are maintained. This type of oven utilizes the principle of a heavy wall between each two oven-chambers. This wall occupies some room, and therefore more space per unit of production, yet it has several material advantages. It supports the main body of the oven-structure and carries, without difficulty, the weight of the heavy charging-cars, which, when loaded, may weigh more than 20 tons. It permits that part of the oven-structure which is subjected to the highest heats to be readily repaired, or even entirely replaced, without effecting the integrity of the main structure, and also without stopping adjacent ovens. In cases where the coal is hard on the oven bricks, or where a large percent-

age of water, as in washed coal, causes a severe shock to the red-hot bricks when charged, or after the plant has become old, this is an important feature. Another value of these intermediate walls is that they act as a reservoir of heat. They accumulate heat during the coking process, and when fresh coal is charged they come to the assistance of the burning gas, and help the oven pick up its heat and maintain a coking temperature.

While the earlier by-product oven-plants were simpler in design and equipment, the modern plant is almost entirely mechanically operated, and electrically-driven machinery has taken the place of most of the hand-labor. The following data illustrate the distribution and consumption of power in a plant of a capacity of 1,300 tons of coal per day:

Daily Power Consumption in Kilowatt-Hours for Various Operations.

Lighting	599
Pumps handling ammonia liquor	390
Scrubbers and pumps in by-product recovery-plant	1,283
Coal-charging and coke-pushing	192
Coal-conveyors	393
Coal-unloading	282
Coal-storage	102
Crushing and pulverizing	287
Coke-handling	686
Pumping water	1,800
	6,014

During the development of the by-product oven in the last few years much study has been given to increasing the effectiveness and economy of the apparatus for recovering the by-products. This recovery consists essentially in the cooling of the gas, which causes the condensation of much of the tar-vapor and water-vapor, which latter brings down with it part of the ammonia. After cooling, the gas is scrubbed in contact with water, sometimes by passing it through tall towers through which water is showered, sometimes by bubbling through water in a series of shallow pans, or by other methods; the object in all scrubbing processes being to bring the gas in contact as intimately as possible with wetted sur-

faces, to take advantage of the strong affinity of water and ammonia. The weak ammonia liquor produced in these processes is distilled by steam, producing either the ammonia liquor of commerce, or, by more refined operations, the purer grades of ammonia. If the ammonia gas from the stills is passed into sulphuric acid, ammonium sulphate, one of the most important artificial fertilizers, is produced.

Much work has been done lately on what are known as direct processes for the recovery of ammonia. In all these processes, the gas is passed directly through a bath of sulphuric acid, thereby turning the ammonia into sulphate. Several such "direct" processes have been worked out, the difference being principally in the method employed for the removal of the tar from the gas, which is then bubbled through the sulphuric acid bath; the ammonium sulphate settles out and is removed and the gas is ready for further treatment. At this point the light oils are removed or the gas is sent direct to the point of consumption. Several methods have been advocated for the utilization of the sulphur in the gas itself as the source of sulphuric acid for making the sulphate. These processes are somewhat complicated, and will not be described here, as they have been fully discussed in the technical journals.

One of the latest applications connecting the manufacture of coke with the other arts is the "gas-oven." This name has been applied to the by-product coke-oven when adapted especially to the manufacture of illuminating-gas. The essential modification is that the gas for heating the ovens is obtained from producers, the ovens being modified to suit this gas, so that the whole of the gas produced from the distillation of the coal in the oven is available for sale as illuminating-gas. This adaptation of the retort oven is attracting considerable attention; several plants are in operation in Europe, and three or four are beginning operation or are in the course of construction in the United States. While producing practically the same gas as other systems employed in coal-gas manufacture, the gas-oven has the advantage of producing a high quality of coke. It also has the advantage in operating-cost, due to the employment of larger units, and carbonizing more coal per unit of labor.

These plants are more especially adapted to the larger installations for gas-manufacture.

In discussing the use of by-product coke for metallurgical purposes, the statement is often made that this coke cannot be as good as bee-hive coke, because the quality of the coke is injured in the manufacture in order to obtain better by-products. This is not the fact, as is borne out by the considerable number of by-product oven-plants now supplying metallurgical coke for furnace and foundry-work. In fact, in a number of localities by-product coke is sold for foundry purposes at a premium over the best bee-hive coke on the market.

One point in which by product oven-operation has improved in recent years is in reliability. In considering the gas, for example, either for gas-engine work or for illuminating purposes, reliability of supply is an absolute essential; and while formerly the supply of gas was uncertain and undependable, contracts are now made which insure a permanent and reliable supply that can be depended upon, like any other manufactured product. The sales of oven-gas for illuminating purposes now exceed 40,000,000 feet per day.*

The manufacture of by-product coke is coming to be not only an operation for the manufacture of coke and the saving of such incidental products as may be obtained, but rather an industry where coal is distilled for the purpose of producing several products, such as coke, tar, ammonia, benzol, gas, and perhaps others, each made of the best quality, and each important in maintaining the earnings of the plant. The growth of chemical manufactures in America and the greater demand for the products which supply these industries add permanency and reliability to the market, and at the same time the by-product oven furnishes a reliable supply of raw materials to important industries, which, although in some cases still in embryo here, have attained great proportions in Europe, and doubtless will grow to large importance in this country.

To the student of social economics it appears clear that the general adoption of by-product ovens will exert its influence on commercial conditions, the steady opera-

*1912.

tion of these plants being a factor in maintaining the prices of coke, and hence, indirectly, prices of iron products, thus helping not a little the elimination of those violent fluctuations in iron prices, which have been a fruitful cause of the speculations and industrial depressions which so seriously affect both the employer and the employee. These plants may also have their effect on our industrial life by influencing industries to concentrate in the larger centers in order to take advantage of the raw materials which they furnish, the supply of power which may be obtained from the gas produced, and the opportunities which the plants themselves furnish for the employment of various classes of labor.

THE MANUFACTURE OF COKE.

BY F. E. LUCAS, SYDNEY, N. S.

This paper is offered with considerable diffidence, since some of the statements made may not agree with the opinions of other members of the Institute. What I give is the result of some years of experience in the operation and construction of coke-ovens, and observation of plants in America and Europe.

Although my title is "The Manufacture of Coke," I have found it impossible to do justice to the subject without touching on a number of points which, while not strictly involved in the making of coke, yet are of paramount importance from an economic standpoint. There are, indeed, many points of interest, on each of which a separate paper of considerable length might be written, but the scope of my paper will permit me only to touch lightly some of them, in the hope that what I say will promote a full discussion on the whole question. Those of us who are interested in the manufacture of coke are under an obligation to the American Institute of Mining Engineers, which has opened its meetings to the discussion of this subject. I do not believe that there is any question today more worthy or more in need of discussion. When geologists and mining men tell us that, at the present rate of consumption, our coal fields will be exhausted in a few generations, we should welcome any means that will conserve these deposits as far as possible, and give us the greatest amount of heat or power from every ton mined.

I shall try to show that much can be done in this direction through the by-product coke-oven, and that it should stand second to none as an economic factor in the industrial world.

I shall here deal exclusively with the by-product oven, except for the comparative statement I have prepared, showing the saving to be effected by coking in

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by-product instead of bee-hive ovens. It should be borne in mind that this comparison is only for one particular coal, and while other coals may give some better and some poorer results, as far as by-products and yield are concerned, yet it will serve to show the tremendous advantage that by-product ovens have over any other type.

Coke might be called coal with the volatile matter distilled off. And yet coke, as we mean it, and as it must be produced for metallurgical purposes, must be something more than this. It must conform to certain specifications in respect to physical structure and the percentage of impurities present. We have to produce a coke hard enough to carry the weight of the furnace-burden and successfully withstand the abrasion consequent upon the passage of the stock downward through the furnace or cupola, and at the same time, in order to have the best possible quality, it must not be dense. A well-developed cell-structure is essential, I believe, to the best action and lowest consumption of coke in a furnace.

The impurities in coke are principally sulphur and ash, of which the first gives the most trouble.

In America we have in the past been very fortunate in having available large quantities of coals which are naturally of a good coking quality, and require no preparation before charging, except possibly that of crushing to a certain degree of fineness. It is just as true that the exhaustion of these coals is in sight; and it will then be necessary to use other coals of possibly inferior quality. This will necessitate putting the coal through certain processes before charging, in order to maintain the standard of coke.

If the coal is high in sulphur or ash it will have to be washed to remove as much as possible of these impurities. Washing coal consists primarily in keeping the entire mass of coal so agitated in water that the impurities, by reason of their greater specific gravity, may settle to the bottom and be removed. The mechanical devices employed for doing this are many and varied. Some are good, some fairly so, and some bad; but it is not my purpose in this paper to describe or criticise the various types of apparatus. One thing I would, however, emphasize, namely, that any one type of plant does not necessarily work to the best advantage on every coal.

Each coal should be carefully studied and tested by all possible means before erecting any plant to prepare it for coking. Different coals have different specific gravities, and the ratio between the specific gravity of the coal and that of the impurities also varies in different coals. The manner in which the impurities are associated with the coal also varies greatly, and this in particular will largely affect the size to which the coal should be crushel before washing. We find that some coals will give the best results in washing by crushing to a small size before going to the washer and others give the best results by going to the washer in nut-size. In crushing finely before washing, it is often the case that, where the sulphur is contained in definite strata of pyrites, a large part of the pyrites is crushed to dust or flake form, which is held in suspension in the washer and goes over with the coal. When washing the coarser coal it is (more often than not) found advisable after washing to recrush to the degree of fineness which experience shows will give the best results in the coke for that particular coal.

A further preparation, with which, so far, we have not had to bother much in America, is the compression of the coal into cakes before charging. There are coals which when charged loosely into the oven either will not bond at all, or will not bond sufficiently to make a coke that will stand handling, but which, when crushed very fine and stamped into a cake that can be pushed into the oven, will make a good coke.

It is sometimes claimed that all coal should be stamped before charging, but I cannot agree with that claim, for this reason: a large open cell-structure in the coke, provided the cell-walls are strong enough to carry the burden, gives us a calorific intensity or fierceness of combustion which it is not possible to attain by the use of a dense, close-grained coke; and compressing a coal which gives us under natural conditions such a coke as we desire, only closes in the cell-structure and makes a heavier and denser coke, so that the consumption of coke in a furnace per ton of metal produced would, I believe, be higher, since practically the same bulk, and therefore greater weight, would be used.

However, this does not alter the fact that in many cases compression of the charge is of incalculable benefit to the quality of the coke produced, and as our better coking-coals become exhausted, we shall doubtless find it necessary to resort more largely to both washing and compression, in order to keep up the coke-standard. Of course, that will make the coal going to the ovens cost more than at present; but we shall find that other savings can be effected which will more than offset this added cost.

Both washing and compression are almost universally practiced in Europe, but in spite of this we find that the consumption of coke per ton of metal produced is about on a par with the general practice in America, when the quality of the ores and other conditions are considered. Also, we find that the European countries, particularly England, Germany, and Belgium, can, in spite of the fact that the bulk of their coal has to be prepared for coking, and that they are, in general, using much leaner ores, compete very successfully in the world's markets with America, which, as yet, has not been, to any great extent, confronted with the conditions which obtain on the other side. What they have done we can do, and one of the chief reasons why they can compete is because of their avoidance of waste, and their economy in small things. This is most noticeable in the general adoption of by-product ovens and the saving of all possible by-products.

The following description of the process of making coke and recovering by-products will, I think, be applicable to all types of by-product ovens:

The coking-chamber is rectangular in shape, from 30 to 40 feet long, 6 to 12 feet high, and 16 to 24 inches wide, taking coal-charges of from 5 to 15 tons per oven. The walls are built to contain an arrangement of flues and chambers in which the gas is burned to keep the oven at the required temperature. Underneath the oven-structure are the regenerators, through which the burnt gases pass after heating the oven-walls, the checker-work in the regenerators absorbing the heat from these gases on their way to the stack. At regular intervals the gas is reversed and passes through a second regenerator, and the air for combustion of the gas is drawn up

through the one just heated. By this means air at a temperature of 1,000° to 1,800° F. is supplied for combustion of the gas.

On top of the coking-chamber is a standpipe, or ascension-pipe, connected with the gas main leading to the condensing plant.

The coal-charge is either dropped in through holes in the top of the oven, or, if compressed, is pushed in through the end door; and then the oven is tightly sealed, to avoid loss of gas, or the possible drawing-in of air, which would lead to a partial combustion of the charge and dilution of the gas. The gas driven off ascends through the standpipe into the collecting main, and is then drawn to the condensing plant by means of suitable exhausters.

The recovery of by-products in their first form takes place in the condensing plant. During the past few years there have been so many new developments in by-product recovery apparatus that it will be necessary to outline briefly the different processes by means of which the tar and ammonia may be extracted from the gas. The older method was to pass the gas through a series of coolers, bringing it down gradually to the vicinity of from 80° to 90° F., then pass it through the tar-scrubbers, and then through the ammonia-washers, where the gas was brought by various means into intimate contact with water. The water absorbed the ammonia, and this ammonia liquor was then distilled by steam, the ammonia vapor being driven off, and, in turn, absorbed in a bath of sulphuric acid, in which the ammonium sulphate was precipitated, and afterwards extracted and dried, ready for shipment.

The next process was a semi-direct one, in which the gas was cooled sufficiently to allow the tar to be extracted by the ordinary cooling method, and then the gas was heated up again and all passed through the sulphuric acid bath, which absorbed all the ammonia, while the gas passed on to the holder or oven. The sulphate in this case was precipitated and prepared for shipment as in the previous process.

In the semi-direct process a certain amount of weak ammoniacal liquor, consisting of the moisture which was condensed out of the gas in the original cooling, has

to be dealt with in stills, the same as in the first process. The quantity of the liquor to be so dealt with will depend on the moisture in the coal charged into the ovens.

A third—the direct—process, consists in taking the gas direct from the ovens without cooling, extracting the tar at this high temperature by specially designed apparatus, and then passing the whole of the gas through the acid bath, as in the previous process. By this method there is no liquor to be dealt with and there is also no lime needed in the process, as in the case where liquor has to be distilled and a certain amount of milk of lime has to be added to release the so-called fixed compounds of ammonia in the liquor.

There is still another process, as yet in the experimental stage, in which the gas is cooled and the tar extracted as in the process first described, but the ammonia is recovered in the form of sulphate by utilizing the hydrogen sulphide in the gas instead of sulphuric acid.

A detailed description or discussion of all the different types of ovens and by-product recovery apparatus would occupy more space than I believe could be granted for this paper.

The coke is discharged from the ovens by means of a ram, and is received either on a quenching-wharf or in one of the many types of quenching-cars or machines. In one type the entire bottom of the oven is dropped, letting the charge fall out into a quenching-car underneath.

The quenching of the coke is important from both standpoints of moisture-content and of strength. If the coke gets too much water, the cells will suck themselves full as they cool, and there will not be heat enough left to expel this excessive moisture. At the same time, the rapid formation of steam has a tendency to crack the coke and weaken it materially. The ideal quenching of coke can, I think, be shown by immersing a piece in water, just for a moment, immediately after it comes from the ovens, and then leaving it for about 20 minutes. The water has just chilled the outside and stopped any tendency to combustion there. The inside will die out for want of air, and at the same time there will be sufficient heat to dry out the moisture from the other cells. It is probably not possible in actual practice to get such

results as we would in a small experiment, but the nearer we approach to it, the better the product will be.

The effect of moisture in the coke is one on which opinions may differ. Naturally, if one is buying coke by weight and has to have it hauled a considerable distance, one does not care to pay for the moisture-content or pay freight on it. Even if the moisture is determined and only dry coke paid for, there is still the question of freight, which is an important one when large quantities of coke are being used.

The effect of moisture in the coke on the action of the furnace cupola itself, is not so clear to me. In the foundry-cupola, where the ratio of coke to iron melted is so low and the distance between the top and the melting zone so short, I can readily see how the question of moisture may be very important; but in the blast-furnace we have a very different condition. I do not see how a reasonable amount of moisture in the coke can affect the melting-zone of the furnace or the reducing action of the gas on the ore. There is a temperature at the top of the furnace, where the coke is charged, high enough to thoroughly dry out the moisture before the coke gets far enough down to do any good, and the moisture is carried off with the gas. In fact, I believe there are some furnace-plants where the coke is sprayed with water before charging, in order to keep the top heat down below the danger limit.

Then comes the question of the effect of the moisture on the gas itself. As long as the moisture is not high enough to limit the heats required to be raised on the stoves, I cannot see that it has done any harm.

The effect of longer or shorter coking hours or higher or lower temperatures on the quality of the coke is something that can only be determined by actual experiment with each different kind of coal. We can make laboratory tests on a small scale to test the coking qualities of a coal and its yield of by-products, but I would not care to build a plant to deal with a certain coal and base my calculations entirely on laboratory tests.

In selecting a design of oven for coking, regard should be had to simplicity as far as possible, accessibility for inspection and repairs, such arrangement of combustion-chambers and flues as will give a uniform

temperature in all parts of the oven; and a by-product plant that will turn the gas out free from tar, and with only traces of ammonia, at the same time producing ammonium sulphate of good color; all with due regard to the special conditions presented by a given coal and a given locality.

The advantage of a by-product oven over other types and its value as an economic factor lie not only with the coke, in that it gives a higher yield of coke from a given weight of coal, but also in the by-products and surplus gas.

The ammonium sulphate recovered finds a ready market, and the demand for this product as a fertilizer must always increase as the population of the country increases, and the farm and garden lands require more fertilization.

The tar also finds a ready market, and this also is bound to increase. The value of tar by-products is rising as the demand increases. It would take a book in itself to describe the many products made from tar, all the way from pitch to drugs and perfumes. But we will consider the main products alone, viz, pitch, creosote oils, and light oils. For road-making, roofing, and briquetting, there will always be a market for the pitch. With the exhaustion of our timber lands in sight, we must either do something to conserve them or find a substitute. Railroad companies and mine-owners will find it to their advantage to creosote all railroad ties and pit-timbers as well as bridge and pier timber. The lighter oils will be used in internal combustion engines.

Probably the greatest waste the country has ever seen, or ever will see, has been going on for all the years we have been making coke in bee-hive ovens and burning the gas out in the air. Making coke in by-product ovens, and utilizing the gas by the most commercial means, will revolutionize the production of power. It has already done so, most notably in Germany; and we must come to it sooner or later. The sooner we arrive at that point the better for the industries of the country, and the more we shall have done towards conserving our coal resources.

A modern by-product oven, run at a reasonable capacity, will give 50 per cent or more of surplus gas

from a coal of about 28 per cent volatile-content. The surplus gas is the gas over and above the quantity needed to keep the oven up to the required temperature. This surplus gas should run from 450 to 500 B.t.u. per cubic foot. The quantity of surplus gas is approximately 5,000 cubic feet; hence, 5,000 times 450 equals 2,250,000 B.t.u. per ton of coal carbonized is available for the production of power equal to 93,750 B.t.u. per hour. The builders of gas engines tell us we can get 1 h-p. on a heat-consumption of 11,000 B.t.u. On that basis, we find 8.5 h-p. per hour from the surplus gas from 1 ton of coal.

The surplus gas can also be used for illuminating purposes. This is done at some plants in this country and at a great many in Germany. By installing two collecting mains on top of the ovens, the rich gas, given off during the earlier hours of the coking time, can be collected in one main, and the leaner gas in the second. By this means gas of 650 to 750 B.t.u., or from 16 to 19 candle-power, can be delivered direct from the ovens without enriching. The lean gas is still of sufficiently high calorific value for heating the ovens. Gas from by-product ovens can be piped for hundreds of miles if necessary. Again, the gas may be used for steam-raising or for heating all manner of furnaces, or, in conjunction with steel-works, can be used in a steel-furnace instead of producer-gas. The recent investigations by Professor Bone have shown how by flameless combustion we can get 95 per cent of efficiency out of the gas we burn.

In any of the above ways the gas can be used with great economy; but I believe the production of power from gas engines opens up the largest field.

In the year 1911 there was produced in America approximately 29,338,000 tons of coke, of which approximately 21,448,000 tons was produced in bee-hive ovens. I do not know the figures for the average volatile-content of the coal that went to make this coke, but assuming a fairly low volatile coal of say 24 per cent, to produce 21,000,000 tons of coke in by-product ovens would take about 26,000,000 tons of such coal. Allowing the small amount of 4,000 cubic feet of surplus gas per ton of coal, and 15 pounds of ammonium sulphate, and 7 gallons of tar, and allowing the surplus gas to furnish only 400 B.t.u. per cubic foot, we find that we would have 26,000,-

000 times 4,000, equal to 104,000,000,000 cubic feet of gas per year; this at 400 B.t.u. per cubic foot equals 41,600,-000,000,000 B.t.u.; reduced to hours, equals 4,748,858,447 B.t.u., at 11,000 B.t.u. per h-p.-hr., equals 431,714 h-p. Or, allowing the value of 10 cents per 1,000 cubic feet for the gas, we have the sum of $10,400,000. Of ammonium sulphate we have 174,107 gross tons at a value of approximately $60 per ton, equal to $10,446,420. Of tar we have 182,000,000 gallons, worth, at 2 cents per gallon, $3,640,-000. Total value of gas, ammonia, and tar, $24,486,420.

I do not doubt that the coal from which the coke was made would have given better results than I have shown here, but even at these conservative figures we can see what a loss there has been.

The above amount is 7 per cent on about $350,000,-000, a sum which would build by-product ovens enough to carbonize 125,000,000 tons if coal yearly. Besides this loss, there has been the loss of the coal burned in the bee-hive oven. Allowing 64 per cent as a fair yield for the bee-hive and 78 per cent for the by-product ovens, there would be a loss exceeding 6,000,000 tons of coal. This at $1 per ton added to the other loss gives us a grand total of over $30,000,000 lost in one year. It seems to me that this is well worth "getting after." Much can be done if we approach this subject in the same manner, and give it the same study and attention as has been given in past years to questions pertaining to mining and metallurgy.

COMPARISON BETWEEN BEE-HIVE AND BY-PRODUCT OVENS.

Bee-Hive.

Ordinary type, 12.5 ft. in diameter.
Cost from $700 to $1,200 per oven.
Produces 4 net tons of coke in 48 hr., equal to 2 net tons in 24 hrs.
Yield of coke from coal, 60 per cent.
By-products and surplus gas, none.

By-Product Ovens.

Oven charge, 9 tons.
Coking-time, 24 hrs.
(Ovens may be larger or smaller than this, but 9 tons would probably be about the average charge for the modern type of oven).

Coke proluced on 70 per cent yield, equals 6.3 tons of coke per oven in 24 hrs.

By-Products.

Ammonium sulphate, 22 lbs. per net ton of coal, equal to 31 lbs. per net ton of coke. Value 2.25 cents per lb. above cost of manufacture, equals 70 cents per ton of coke made.

Tar. 8:5 gal. per ton of coal, equal to 10.7 gal. per ton of coke, at 2 cents per gal., equals 21 per ton of coke.

Surplus gas, 5,000 cu. ft. per ton of coal, equals 7,-143 cu. ft. per ton of coke, at 10 cents per 1,000 cu. ft., equals 71 cents per ton of coke.

Total Value of By-Products as above.

Ammonium sulphate	$0.70
Tar	0.21
Gas	0.71
	$1.62 per ton of coke.

Add to the above the difference between 60 per cent yield in bee-hive ovens and 70 per cent in by-product ovens on the same coal. Taking coal at $1.50 per ton:

Coal per ton of coke produced in bee-hive oven	=$2.50
Coal per ton of coke produced in by-product oven	= 2.14
Balance in favor of by-product oven	=$0.36

So that the total saving in coal and by-products equals $1.62 plus $0.36, equals $1.98 per ton of coke made, equals $12.47 per oven in 24 hrs., equal to $4,551.55 per oven per year.

For a plant of 100 ovens, saving equals $455,155 per year.

Cost of 100-oven plant complete, approximately $1,000,000. A 100-oven plant of above capacity will produce 630 tons of coke per day, equal to 229,950 tons per year, working on 24 hr. coking time.

If benzol is recovered it will further add to the income from by-products.

ELEVATIONS ABOVE SEA OF POINTS IN KENTUCKY.

Compiled from Co-operative Work of the Kentucky Geological Survey and United States Geological Survey and From the Various Railroad and River Surveys

Place.	County.	Station.	Elevation.
Adairville	Logan	L. & N. R. R.	589
Addison	Breckenridge	L. H. & St. L. R. R.	371
Aden	Carter	C. & O. R. R.	626
Aetnaville, P. O.	Ohio	U. S. B. M.	414
Alexander	Fulton	U. S. C. & G. S.	338
Allen	Floyd	U. S. B. M.	638
Allensville	Todd	L. & N. R. R.	554
Alley	Boyd	U. S. B. M.	629
Almo	Calloway	N. C. & St. L. R. R.	440
Alms House	Jefferson	I. C. R. R.	464
Alonzo	Floyd	U. S. B. M.	643
Alphoretta	Floyd	U. S. B. M.	652
Alpine	McCreary	Q. & C. R. R.	1,005
Altamont	Laurel	L. & N. R. R.	1,163
Alton	Anderson	S. R. R.	722
Alton	Anderson	U. S. B. M.	839
Ambrose	Jessamine	U. S. B. M.	851
Anchorage	Jefferson	U. S. B. M.	724
Anderson	Logan	U. S. B. M.	637
Anderson	Todd	E. & G. R. R.	650
Anderson Ferry	Boone	L. W. in Ohio River	429
Andersonville	Daviess	U. S. B. M.	465
Anton	Hopkins	U. S. B. M.	664
Apex	Christian	U. S. B. M.	409
Argillite	Greenup	E. K. R. R.	524
Argillite	Greenup	U. S. B. M.	567
Argyle	Powell	L. & E. Station	722
Arlington	Carlisle	B. M. near I. C. R. R. Station	363
Artemus	Knox	L. & N. R. R.	995
Ashbyburg	Hopkins	U. S. B. M.	385
Ashcamp	Pike	U. S. B. M.	1,084
Ashland	Boyd	C. & O. R. R.	552
Ashland	Boyd	L. W. in Ohio River	486
Askin	Breckenridge	L. H. & St. L. R. R.	613
Athens	Fayette	C. & O. R. R.	1,006
Athol	Breathitt	L. & E. R. R. Station	744
Auburn	Logan	L. & N. R. R.	605
Augusta	Bracken	L. W. in Ohio River	444
Augusta	Bracken	C. & O. R. R.	505
Austerlitz	Bourbon	L. & N. R. R.	918
Auxier	Johnson	U. S. B. M. C. & O. Station	630
Avenstoke	Anderson	L. S. R. R.	733
Avon	Fayette	L. & E. Station	944
Bacon Creek	Hart	L. & N. R. R.	621
Bagdad	Shelby	U. S. B. M. R. R. Station	912
Baker	Caldwell	U. S. B. M. R. R. Station	471
Bakersport	Hopkins	U. S. B. M.	397
Ballard	Anderson	B. M. near P. O.	686

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Ballard	Floyd	U. S. B. M.	683
Bancroft	Muhlenberg	U. S. B. M.	486
Bank Lick	Kenton	L. & N. R. R.	829
Barboursville	Knox	L. & N. R. R.	960
Bardstown	Nelson	L. & N. R. R.	637
Bardstown Jct.	Bullitt	L. & N. R. R.	417
Bardwell	Carlisle	B. M. on C. H.	390
Barnes	Carroll	L. & N. R. R.	665
Barnsley	Hopkins	U. S. B. M.	483
Barren Fork	McCreary	Q. & C. R. R.	1,281
Barren River	Barren	Lock 1. Top of wall	422
Bart	Wayne	Cumberland River	569
Bart	Wayne	U. S. B. M. near P. O.	641
Baskett	Henderson	U. S. B. M.	397
Baugh	Logan	L. & N. R. R.	443
Beals	Henderson	U. S. B. M.	390
Beard's	Oldham	L. & N. R. R.	761
Beattyille	Lee	L. W. in Kentucky River	618
Beattyville Jct.	Lee	U. S. B. M. L. & E. Station	690
Beattyville Jct.	Lee	L. & E. R. R.	713
Beaver Creek	Floyd	C. & O. R. R.	651
Beaver Dam	Ohio	U. S. B. M.	413
Beaver Gap	Knott-Letcher	U. S. B. M.	1,492
Beckley	Jefferson	U S. B. M. L. & N. Station	599
Beda	Ohio	U. S. B. M.	546
Beddow	Pike	C. & O. R. R.	1,314
Bedford	Bourbon	L. & N. R. R.	892
Beechgrove	McLean	U. S. B. M.	408
Belamy Store	Ohio	U. S. B. M.	440
Belcourt	Webster	U. S. B. M.	397
Bellevue	Henry	L. & N. R. R.	875
Bell's Mill Ford	Bullitt	U. S. B. M.	423
Belmont	Bullitt	L. & N. R. R.	431
Belton	Muhlenberg	L. & N. R. R.	409
Benson	Franklin	U. S. B. M. R. R. Station	598
Benton	Marshall	N. C. & St. L. R. R.	380
Berea	Madison	L. & N. R. R.	943
Berkley	Carlisle	M. & O. R. R.	355
Berry	Harrison	L. & N. R. R.	640
Bethany	Jefferson	U. S. B. M.	452
Bethlehem	Hardin	I. C. R. R.	732
Beulah	Hopkins	U. S. B. M.	540
Bevier	Muhlenberg	L. & N. R. R.	400
Big Clifty	Grayson	I. C. R. R.	682
Big Sandy Jct.	Boyd	C. & O. R. R.	558
Big Sandy River	Boyd	L. W. at mouth	498
Big Sandy River	Lawrence	L. W. at mouth of Big Blaine	521
Big Sandy River	Lawrence	L. W. at Louisa	526
Big Sandy River	Martin	L. W. at mouth of Rockcastle	548
Big Sandy River	Martin	L. W. at Richardson	549
Big Sandy River	Martin	L. W. at Warfield	587
Big Sandy River	Johnson	L. W. at mouth of Paint Creek	587
Big Sandy River	Floyd	L. W. at mouth of Johns Cr.	594

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Big Sandy River	Floyd	L. W. at Prestonsburg	606
Big Sandy River	Floyd	L. W. at mouth of Mud Creek	637
Big Sandy River	Pike	L. W. at Pikeville	660
Big Sandy River	Pike	L. W. at Breaks of Sandy	854
Big Spring	Bullitt	L. & N. R. R.	514
Birk	Daviess	U. S. B. M.	382
Bishop	Jefferson	L. S. R. R.	459
Blackburn	Union	U. S. B. M.	348
Blackford	Webster	U. S. B. M.	362
Blacky	Letcher	L. & E. R. R.	998
Blanchet	Grant	Q. & C. R. R.	953
Blandville	Ballard	Weather Bureau	445
Bloomfield	Nelson	U. S. B. M.	669
Bloomfield	Nelson	L. & N. R. R.	595
Blue Cut	Logan	L. & N. R. R.	410
Bluff City	Henderson	U. S. B. M.	394
Bluff Spring	Christian	U. S. B. M.	573
Boaz	Graves	I. C. R. R.	387
Bohon	Mercer	U. S. B. M.	894
Bolts Fork	Boyd	U. S. B. M.	653
Bonanza	Floyd		640
Bonds	McCracken	I. C. R. R.	361
Bonita	Woodford	U. S. B. M.	897
Bonnieville	Hart	L. & N. R. R.	646
Boones Fork	Letcher	U. S. B. M.	1,264
Boonesboro	Clark	L. W. in Kentucky River	538
Boone's Gap	Madison	L. & N. R. R.	1,130
Booneville	Owsley	L. W. in Kentucky River	651
Booth's	Hardin	L. & N. R. R.	425
Bordley	Union	U. S. B. M.	416
Bosco	Floyd	B. M. mouth of Brush Cr.	675
Boston	Jefferson	U. S. B. M.	615
Boston	Nelson	L. & N. R. R.	431
Bostonia	Mercer	U. S. B. M.	747
Bourne	Garrard	U. S. B. M.	928
Bowling Green	Warren	Weather Bureau	469
Boxville	Union	U. S. B. M.	443
Boyd	Harrison	L. & N. R. R.	674
Bracht	Kenton	Q. & C. R. R.	919
Bracktown	Fayette	U. S. B. M.	863
Bradshaw	Todd	E. & G. R. R.	580
Brannon	Jessamine	U. S. B. M.	1,041
Brandenburg	Meade	L. W. in Ohio River	356
Brandenburg Sta.	Meade	L. H. & St. L. R. R.	594
Bratcher	Grayson	I. C. R. R.	445
Braxton	Mercer	U. S. B. M.	863
Breaks of Sandy	Pike	L. W. in Big Sandy River	854
Breton	Webster	U. S. B. M.	384
Bridge Fork	McCreary	Q. & C. R. R.	1,314
Brinkley	Knott	U. S. B. M.	1,178
Bristow	Warren	L. & N. R. R.	517
Broadhead	Rockcastle	L. & N. R. R.	903
Bromley	Owen	U. S. B. M.	489

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Bronston	Pulaski	Post Office	818
Brooks	Bullitt	L. & N. R. R.	490
Broshears	Mason	C. & O. R. R.	505
Brownsboro	Oldham	L. & N. R. R.	770
Brumfield	Boyle	L. & N. R. R.	1,014
Brummett	Whitley	L. & N. R. R.	982
Brush Creek	Rockcastle	L. & N. R. R.	924
Bryan	Jefferson	U. S. B. M.	659
Buchanan	Lawrence	C. & O. R. R.	558
Buckner	Oldham	L. & N. R. R.	792
Buda	Fulton	I. C. R. R.	428
Buechel	Jefferson	U. S. B. M.	500
Buel	McLean	U. S. B. M.	446
Buena Vista	Lewis	C. & O. R. R.	523
Burdine	Letcher	U. S. B. M.	1,443
Burgess	Boyd	U. S. B. M.	565
Burgin	Mercer	U. S. B. M.	911
Burlington	Boone	U. S. B. M. C. H.	848
Burnside	McCreary	L. W. in Cumberland River	589
Burnside	McCreary	Q. & C. R. R.	770
Bush	Breathit	L. & E. R. R.	787
Butler	Pendleton	L. & N. R. R.	604
Cadentown	Fayette	C. & O. R. R.	1,035
Cadmus	Lawrence	U. S. B. M.	597
Cairo	Henderson	U. S. B. M.	465
Calhoun	McLean	U. S. B. M.	392
California	Campbell	C. & O. R. R.	496
Calvary	Marion	L. & N. R. R.	609
Calvert	Marshall	I. C. R. R.	443
Campbellsburg	Henry	L. & N. R. R.	896
Camp Dick Robinson	Garrard	U. S. B. M.	915
Campton Jct.	Powell	U. S. B. M. L. & E. Station	747
Cane Spring	Bullitt	L. & N. R. R.	623
Caney	Pike	U. S. B. M.	785
Caneyville	Grayson	I. C. R. R.	[illegible]99
Cannonsburg	Boyd	U. S. B. M.	604
Carlinburg	Henderson	U. S. B. M.	377
Carrollton	Carroll	L. W. in Ohio River	413
Carrollton	Carroll	L. & N. R. R.	464
Carrs	Lewis	C. & O. R. R.	532
Carter	Carter	C. & O. R. R.	678
Catalpa	Lawrence	U. S. B. M.	563
Catlettsburg	Boyd	C. & O. R. R.	552
Catlettsburg	Boyd	L. W. in Ohio River	498
Catnip Hill	Jessamine	Q. & C. R. R.	975
Cave City	Barren	L. & N. R. R.	613
Cave Hill	Warren	U. S. B. M.	660
Cave Spring	Logan	L. & N. R. R.	588
Cayce	Fulton	M. & O. R. R.	400
Cecilia	Hardin	I. C. R. R.	711
Cecilian Jct.	Hardin	I. C. R. R.	637
Cedar Grove	Pulaski	Q. & C. R. R.	847
Centertown	Ohio	U. S. B. M.	449

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Central City	Muhlenberg	U. S. B. M.	426
Cerulean	Trigg	U. S. B. M. Station	458
Chambers	Montgomery	C. & O. R. R.	831
Chapman	Lawrence	U. S. B. M.	587
Chatteroy, W. Va.		N. & W. R. R.	655
Chavies	Perry	L. & E. R. R.	797
Chenowee Tunnel	Breathitt	L. & E. R. R.	938
Cherokee	Lawrence	U. S. B. M.	646
Chestnut Mtn.	Knott	U. S. B. M.	1,825
Chicago	Marion	L. & N. R. R.	673
Chilesburg	Fayette	C. & O. R. R.	1,006
Christiansburg	Shelby	U. S. B. M. R. R. Station	906
Clark	Jefferson	L. S. R. R.	674
Clark	Mason	L. & N. R. R.	754
Clark	Shelby	U. S. B. M.	685
Clark's	McCracken	I. C. R. R.	351
Claxton	Caldwell	U. S. B. M.	450
Clay	Webster	U. S. B. M.	380
Clay City	Powell	U. S. B. M. L. & E. Station	628
Clayhole	Breathitt	U. S. B. M. op. P. O.	824
Cleaton	Muhlenberg	U. S. B. M.	442
Cleopatra	McLean	U. S. B. M.	498
Cliff	Floyd	U. S. B. M. C. & O. Station	636
Clifty	Todd	U. S. B. M.	805
Clinton	Hickman	B. M. at Court House	389
Cloverport	Breckenridge	L. W. in Ohio River	340
Cloverport	Breckenridge	L. H. & St. L. R. R.	387
Clyffeside	Boyd	C. & O. R. R.	548
Coalrun	Pike	C. & O. R. R.	676
Coalton	Boyd	U. S. B. M.	615
Cobb	Caldwell	U. S. B. M. R. R. Station	463
Coiltown	Hopkins	U. S. B. M.	431
Colburg	Adair	Kentucky Geological Survey	730
Colby	Clark	C. & O. R. R.	1,023
Colesburg	Hardin	L. & N. R. R.	425
Columbus	Hickman	M. & O. R. R.	313
Columbus	Hickman	L. W. in Mississippi River	270
Comer	McLean	U. S. B. M.	460
Concord	Lewis	C. & O. R. R.	518
Concordia	Meade	L. W. in Ohio River	346
Congleton	McLean	U. S. B. M.	464
Conner	Shelby	U. S. B. M. L. & N. Station	706
Consolation	Shelby	L. S. R. R.	868
Constance	Boone	B. M. on P. O.	497
Conway	Rockcastle	L. & N. R. R.	951
Coolers Knob	Caldwell	U. S. B. M.	743
Copeland	Breathitt	L. & E. R. R.	765
Coral Ridge	Jefferson	U. S. B. M.	500
Coraville	Henderson	U. S. B. M.	412
Corbin	Whitley	L. & N. R. R.	1,046
Corinth	Grant	Q. & C. R. R.	953
Cornishville	Mercer	U. S. B. M.	736
Corydon	Henderson	U. S. B. M.	459

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Covington	Kenton	C. & O. R. R.	522
Covington	Kenton	B. M. on P. O.	513
Cowan	Fleming	L. & N. R. R.	927
Crab Orchard	Lincoln	L. & N. R. R.	919
Crayne	Crittenden	U. S. B. M. R. R. Station	643
Crescent Hill	Jefferson	L. & N. R. R.	515
Crescent Springs	Kenton	Q. & C. R. R.	785
Crider	Caldwell	U. S. B. M. R. R. Station	487
Crittenden	Grant	Q. & C. R. R.	908
Crockettsville	Breathitt	U. S. B. M.	710
Crofton	Christian	U. S. B. M.	608
Cromwell	Ohio	U. S. B. M.	482
Cropper	Shelby	L. & N. R. R.	889
Crow-Hickman	Daviess	U. S. B. M.	404
Crum, W. Va.		N. & W. R. R.	617
Cullen	Union	U. S. B. M.	476
Cumberland Falls	McCreary	L. W. ½ mi. above Falls	843
Cumberland Falls	McCreary	L. W. 300 yds. below Falls	789
Cumberland F. Sta.	McCreary	Q. & C. R. R.	1,256
Cumberland Gap	Tri-State Cor.		1,648
Cumberland Gap	Bell		1,665
Cumberland River	Wayne	Mill Spring Ford	588
Cumberland River	McCreary	L. W. Burnside	589
Cumberland River	Pulaski	L. W. at mouth of Fishing Cr.	577
Cumberland River	Pulaski	L. W. at mouth of Rockcastle River	662
Cumberland River	Bell	L. W. at Pineville	951
Curdsville	Daviess	U. S. B. M.	393
Curry	Mercer	L. S. R. R.	828
Cynthiana	Harrison	L. & N. R. R.	700
Cyrus	W. Va.	N. & W. R. R.	569
Dalton	Hopkins	U. S. B. M.	438
Daniel Boone	Hopkins	U. S. B. M.	494
Danville	Boyle	Q. & C. R. R.	955
Danville C. H.	Boyle	U. S. B. M.	989
Davenport	Butler	U. S. B. M.	461
Davidson	Ohio	I. C. R. R.	429
Dawson Springs	Hopkins	U. S. B. M.	436
Dayton	Campbell	C. & O. R. R.	542
Deanefield	Ohio	I. C. R. R.	460
Deep Cut	Carter-Lewis	C. & O. R. R.	1,036
Deerlick	Logan	U. S. B. M.	683
DeKoven	Union	U. S. B. M. R. R. Station	365
Delaware	Daviess	U. S. B. M.	397
Delorme	W. Va.	N. & W. R. R.	728
Dema	Knott	U. S. B. M.	711
Dempster Jct.	Breckinridge	L. H. & St. L. R. R.	408
Denton	Carter	U. S. B. M.	669
Denver	Johnson		629
Depoy	Muhlenberg	U. S. B. M.	500
Derby	Webster	U. S. B. M.	369
Dermont	Daviess	U. S. B. M.	478
Devon	W. Va.	N. & W. R. R.	761

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Dexter	Calloway	N. C. & St. L. R. R.	424
Diamond Springs	Logan	U. S. B. M.	424
Dixie	Henderson	U. S. B. M.	457
Dixon	Boone	Q. & C. R. R.	928
Dixon	Webster	U. S. B. M. at C. H.	544
Donerail	Fayette	Q. & C. R. R.	882
Dorton	Pike	U. S. B. M.	1,017
Dover	Mason	C. & O. R. R.	508
Drakesboro	Muhlenberg	U. S. B. M.	398
Dravo	Jefferson	L. S. R. R.	599
Drew	Knott	U. S. B. M.	1,296
Dry Ridge	Grant	Q. & C. R. R.	949
Dulaney	Caldwell	U. S. B. M.	547
Dumont	Breathitt	L. & E. R. R.	748
Dunbar	Butler	U. S. B. M.	467
Duncannon	Madison	L. & N. R. R.	989
Dundee	Powell	U. S. B. M. L. & E. Station	711
Dundee	Ohio	U. S. B. M.	424
Dunmor	Muhlenberg	U. S. B. M.	593
Duvall	Scott	U. S. B. M.	840
Dwale	Floyd	U. S. B. M.	649
Eagle	Carroll	L. & N. R. R.	465
Earles	Muhlenberg	U. S. B. M.	512
Earlington	Hopkins	U. S. B. M.	422
East Bernstadt	Laurel	L. & N. R. R.	1,159
East Cairo	Ballard	I. C. R. R.	322
East Eagle	Owen	U. S. B. M.	956
East Louisville	Jefferson	L. & N. R. R.	460
East Point	Johnson	C. & O. R. R.	627
East View	Hardin	I. C. R. R.	761
Eastwood	Jefferson	U. S. B. M. L & N. Station	652
Ebenezer	Mercer	U. S. B. M.	821
Eddyville	Lyon	I. C. R. R.	436
Edjouett	Perry	L. & E. R. R.	884
Edwards	Logan	L. & N. R. R.	532
Ekron	Meade	L. H. & St. L. R. R.	627
Elba	McLean	U. S. B. M.	497
Elic	Knott	U. S. B. M. near P. O.	1,064
Elihu	Pulaski	Q. & C. R. R.	840
Elizabethtown	Hardin	L. & N. R. R.	683
Elkatawa	Breathitt	U. S. B. M. L. & E. Station	746
Elk Chester	Fayette	U. S. B. M.	841
Elkhorn	Franklin	U. S. B. M. R. R. Station	662
Elkhorn City	Pike	C. & O. R. R.	790
Elkin	Clark	L. & N. R. R.	773
Elkton	Todd	E. & G. R. R.	602
Elliston	Grant	L. & N. R. R.	585
Elm Lick	Ohio	I. C. R. R.	456
Elmrock	Knott	U. S. B. M.	1,051
Elmville	Franklin	U. S. B. M.	720
Elmwood	Webster	U. S. B. M.	395
Elva	Marshall	N. C. & St. L. R. R.	360
Eminence	Henry	L. & N. R. R.	922

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Empire	Christian	U. S. B. M.	518
English	Carroll	L. & N. R. R.	466
Ennis.	Muhlenberg	U. S. B. M.	458
Enola Ferry	Butler	U. S. B. M.	404
Enon	Caldwell	U. S. B. M.	464
Enterprise	Carter	C. & O. R. R.	831
Epley's	Logan	L. & N. R. R.	661
Era	Christian	U. S. B. M.	682
Erlanger	Kenton	Q. & C. R. R.	905
Escondida	Bourbon	L. & N. R. R.	907
Estill Furnace	Estill	Foundation	1,261
Eubank	Pulaski	Q. & C. R. R.	1,172
Euclid	Greenup	U. S. B M.	668
Euterpe	Henderson	U. S. B. M.	441
Ewing	Fleming	L. & N. R. R.	903
Ewington	Montgomery	C. & O. R. R.	992
Excelsior	Bell	U. S. B. M. at Coal Mines	1,133
Fairdale	Jefferson	U. S. B. M.	474
Fairfield	Nelson	U. S. B. M.	715
Fair Grounds	Jefferson	U. S. B. M.	727
Faith	McLean	U. S. B. M.	460
Falcon	Hancock	L. H. & St. L. R. R.	364
Falls of Rough	Grayson	L. H. & St. L. R. R.	423
Falmouth	Pendleton	L. & N. R. R.	530
Fariston	Laurel	L. & N. R. R.	1,116
Farmdale	Franklin	U. S. B. M.	849
Farmers	Rowan	C. & O. R. R.	668
Farmersville	Caldwell	U. S. B. M.	580
Faulconer	Boyle	B. M. on natural rock	890
Faywood	Woodford	U. S. B. M.	858
Fenwick	Fayette	U. S. B. M. L. & E. Station	938
Ferndale	Bell	L. & N. R. R.	1,175
Field	Shelby	U. S. B. M. R. R. Station	735
Fillmore	Ballard	I. C. R. R.	322
Filson	Powell	U. S. B. M. L. & E. Station	667
Fincastle	Lee	U. S. B. M. L & E. Station	711
Finchville	Shelby	L. & N. R. R.	679
Fisherville	Jefferson	U. S. B. M.	562
Flanagan	Clark	L. & N. R. R.	850
Flat Lick	Knox	L. & N. R. R.	986
Flat Rock	Caldwell	U. S. B. M.	496
Flat Rock	McCreary	Q. & C. R. R.	1,300
Florence	Boone	U. S. B. M.	935
Florence	McCracken	I. C. R. R.	356
Flournoy	Union	U. S. B. M.	419
Floyds	Pulaski	Q. & C. R. R.	1,136
Ford	Clark	L. & N. R. R.	623
Fordsville	Ohio	I. C. R. R.	476
Forkland	Boyle	U. S. B. M.	807
Fort Estill	Madison	L. & N. R. R.	1,031
Fort Estill Jct.	Madison	L. & N. R. R.	1,036
Fort Gay	W. Va.	N. & W. R. R.	578
Fort Jefferson	Ballard	I. C. R. R.	322

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Fort Thomas	Campbell	U. S. B. M.	852
Foster	Bracken	C. & O. R. R.	499
Fox Creek	Anderson	U. S. B. M.	857
Frankfort	Franklin	L. W. in Kentucky River	470
Frankfort	Franklin	U. S. B. M. on P. O.	512
Franklin	Simpson	L. & N. R. R.	691
Fredonia	Caldwell	U. S. B. M. R. R. Station	404
Fredonia	Caldwell	U. S. B. M.	422
Friendship	Caldwell	U. S. B. M.	525
Frost	Christian	C. & O. R. R.	544
Fruit Hill	Christian	U. S. B. M.	641
Fryer	Caldwell	U. S. B. M.	374
Fullers	Lawrence	C. & O. R. R.	570
Fulton	Fulton	U. S. B. M.	357
Futrell	Trigg	I. C. R. R.	394
Gaithers	Hardin	L. & N. R. R.	644
Gallup	Lawrence	U. S. B. M.	591
Gap in Knob	Bullitt	U. S. B. M.	493
Garfield	Breckenridge	L. H. & St. L. R. R.	780
Garnett	Harrison	L. & N. R. R.	715
Garrison	Lewis	C. & O. R. R.	526
Gates	Rowan	C. & O. R. R.	819
George's Creek	Lawrence	C. & O. R. R.	590
Georgetown	Scott	U. S. B. M.	866
Gest	Henry	U. S. B. M.	509
Gethsemane	Nelson	L. & N. R. R.	458
Gilberts Creek	Lincoln	U. S. B. M.	855
Gilbertsville	Marshall	I. C. R. R.	431
Gishton	Muhlenberg	U. S. B. M.	560
Glade	Marshall	N. C. & St. L. R. R.	392
Glasgow	Barren	G. R. R.	780
Glasgow Jct.	Barren	L. & N. R. R.	623
Glenarvon	Clark	L. & E. R. R.	971
Glencairn	Powell	U. S. B. M. L. & E. Station	784
Glencoe	Gallatin	L. & N. R. R.	542
Glendale	Hardin	L. & N. R. R.	640
Glendeane	Breckenridge	L. H. & St. L. R. R.	433
Glen Hayes	W. Va.	N. & W. R. R.	593
Glenn	Lewis	C. & O. R. R.	543
Golds	Webster	U. S. B. M.	358
Gordon	Muhlenberg	I. C. R. R.	429
Goshen	Oldham	U. S. B. M.	699
Gracey	Christian	I. C. R. R.	495
Graham Station	Muhlenberg	U. S. B. M.	409
Grand Rivers	Livingston	I. C. R. R.	437
Grant	Carter	C. & O. R. R.	671
Gratz	Owen	U. S. B. M.	484
Gravel Switch	Livingston	I. C. R. R.	351
Gravel Switch	Marion	L. & N. R. R.	895
Gray	Knox	L. & N. R. R.	1,096
Grays Branch	Greenup	C. & O. R. R.	533
Grayson	Carter	U. S. B. M. C. H.	685
Grayson Springs	Grayson	I. C. R. R.	658

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Green Castle	Warren	U. S. B. M.	424
Greendale	Fayette	U. S. B. M.	936
Green River		Lock 1, top of wall	361
Green River		Lock 2, top of wall	374
Green River	Edmonson	L. W. in Green river at Dennison's Ferry	398
Green River		Lock 3, top of wall	390
Green River	Hart	L. W. in Green River	399
Green River	Hart	L. W. Cub Run Creek	402
Green River	Butler	Lock 4, top of wall	405
Green River	Hart	L. W. Blue Springs Creek	407
Green River	Butler-Warren	Lock 5, top of wall	419
Green River	Edmonson	Lock 6, top of wall	431
Green River	Hart	L. W. at Rio	436
Green River	Green	L. W. Mouth of Little Barren River	453
Green River	Green	L. W. Greensburg	516
Green River	Green	L. W. Bluff Boone Station	531
Green River	Taylor	L. W. at Atchley's Mill	548
Green River	Taylor	L. W. Griffith's Spring	590
Green River	Adair	L. W. at Plum Point	634
Greensburg	Green	Court House	583
Greenup	Greenup	L. W. in Ohio River	478
Greenup	Greenup	Clerk's Office	540
Greenville	Muhlenberg	U. S. B. M. C. H.	538
Greenwood	McCreary	Q. & C. R. R.	1,203
Grove Center	Union	U. S. B. M. R. R. Station	387
Guffie	McLean	U. S. B. M.	454
Gum Grove	Union	U. S. B. M.	386
Gum Sulphur	Rockcastle	L. & N. R. R.	878
Guston	Meade	L. H. & St. L. R. R.	671
Guthrie	Todd	L. & N. R. R.	517
Habit	Daviess	U. S. B. M.	559
Haddix	Breathitt	L. & E. R. R.	751
Hadensville	Todd	L. & N. R. R.	534
Hadley	Warren	U. S. B. M.	659
Hall's Gap	Lincoln	L. & N. R. R.	993
Hamby Station	Hopkins	U. S. B. M.	412
Hamilton	Ohio	I. C. R. R.	442
Hamlak	Pike	C. & O. R. R.	667
Hampton	Boyd	U. S. B. M.	551
Handshoe	Knott	U. S. B. M.	885
Handyville	Daviess	U. S. B. M.	397
Hansbrough	Hardin	I. C. R. R.	676
Hanson	Hopkins	U. S. B. M.	432
Happy Hollow	Hopkins	U. S. B. M.	381
Harbison	Shelby	U. S. B. M. R. R. Station	792
Hardin	Marshall	N. C. & St. L. R. R.	424
Harding	Union	U. S. B. M. R. R. Station	374
Hardinsburg	Breckenridge	L. H. & St. L. R. R.	700
Hardinsville	Shelby	L. & N. R. R.	534
Harlan	Harlan	U. S. B. M. C. H.	1,197
Harned	Breckenridge	L. H. & St. L. R. R.	720

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Harold	Floyd	C. & O. R. R.	665
Harris	Madison	L. & N. R. R.	1,009
Harrodsburg	Mercer	U. S. B. M. C. H.	871
Harrodsburg Jct.	Mercer	Q. & C. R. R.	900
Harrod's Creek	Jefferson	Weather Bureau	410
Hartford	Ohio	U. S. B. M.	434
Hartley	Pike	U. S. B. M. L. W. in Beaver Cr.	972
Harvieland	Franklin	U. S. B. M.	612
Hatton	Shelby	U. S. B. M. R. R. Station	706
Hawesville	Hancock	L. H. & St. L. R. R.	367
Hawesville	Hancock	B. M. on Court House	423
Hawkins	Christian	U. S. B. M.	759
Hayden	Lincoln	L. & N. R. R.	823
Haynesville	Ohio	U. S. B. M.	476
Hazard	Perry	U. S. B. M.	873
Hazel	Calloway	N. C. & St. L. R. R.	572
Hazle Patch	Laurel	L. & N. R. R.	843
Hearin	Webster	U. S. B. M.	468
Heath	McCracken	I. C. R. R.	423
Hebbardsville	Henderson	U. S. B. M.	421
Hebron	Boone	B. M. on Clove's Store	877
Hedges	Clark	C. & O. R. R.	976
Hedgeville	Boyle	U. S. B. M.	924
Heflin	Ohio	U. S. B. M.	400
Helena	Mason	L. & N. R. R.	869
Hellier	Pike	C. & O. R. R.	1,135
Hemp Ridge	Shelby	L. S. R. R.	731
Henderson	Henderson	L. W. in Ohio River	317
Henderson	Henderson	L. & N. R. R.	432
Henshaw	Union	U. S. B. M. R. R. Station	372
Herman	Union	U. S. B. M.	401
Herndon	Scott	S. R. R.	806
Hesler	Owen	U. S. B. M.	942
Hewlett	W. Va.	N. & W. R. R.	570
Hewletts	Daviess	U. S. B. M.	428
Hickman	Fulton	L. W. in Mississippi River	257
Hickman	Fulton	N. C. & St. L. R. R.	306
Hickory Grove	Graves	I. C. R. R.	415
Higginsport	Bracken	L. W. in Ohio River	445
High Brige	Jessamine	Q. & C. R. R.	762
High Grove	Nelson	U S. B. M.	499
Highland	Union	I. C. R. R.	378
Hikes Point	Jefferson	U. S. B. M.	562
Hillenmeyer	Fayette	U. S. B. M.	939
Hindman	Knott	U. S. B M. on C. H.	1,032
Hinton	Scott	Q & C. R. R.	943
Hippo	Floyd	U. S. B. M.	733
Hitchins	Carter	C. & O. R. R.	613
Hollibush	Knott	U. S. B. M.	872
Holt	Breckenridge	L. H. & St. L. R. R.	374
Hombre	Perry	L & E. R. R.	926
Hoods	Crittenden	U. S. B. M.	444
Hopewell	Greenup	E K. R. R.	557

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Hopkinsville	Christian	L. & N. R. R.	541
Hopson	Caldwell	U. S. B. M.	544
Horse Branch	Ohio	I. C. R R.	476
Horse Cave	Hart	L. & N. R. R.	603
Horton	Ohio	I C. R. R.	427
Huber	Bullitt	L. & N. R. R.	458
Hunnewell	Greenup	E. K. R. R.	523
Huntsville	Butler	U S. B. M.	420
Hyattsville	Garrard	U. S. B. M.	1,035
Ilsley	Hopkins	I. C. R. R.	412
Independence	Kenton	L. & N. R. R.	752
Indian Fields	Clark	U. S. B. M. L & E. Station	746
Iola	Marshall	N. C & St. L. R. R.	352
Irvine	Estill	L. W. in Kentucky River	571
Irvington	Breckenridge	L. H. & St. L. R R.	577
Island	McLean	U. S. B. M.	417
Island Creek	Pike	C. & O. R. R.	686
Ivan	Knott	U. S. B. M.	1,315
Ivel	Floyd	C. & O. R. R.	657
Ivyton	Magoffin		835
Jabez	Russell	U. S. B. M.	1,051
Jackson	Breathitt	U. S. B. M. at C. H.	790
Jamboree P. O.	Pike	Peter Creek	943
Jeffersontown	Jefferson	U. S. B. M.	711
Jellico	Whitley	L. & N. R. R.	937
Jenkins	Letcher	U. S. B. M.	1,527
Jericho	Henry	L. & N. R. R.	850
Jessamine	Jessamine	Q. & C. R. R.	886
Jetts	Franklin	U. S. B. M.	791
Jewell	Pike		1,407
Johnson	Fleming	L. & N. R. R.	898
Jolly	Breckenridge	L. H. & St. L. R. R.	652
Jolly	Daviess	U. S. B. M.	545
Jordan	Fulton	M. & O. R. R.	404
Joyes	Shelby	L. S. R. R.	718
Junction City	Boyle	Q. & C. R. R.	982
Kavanaugh	Boyd	U. S. B. M.	581
Keller	Harrison	L. & N. R. R.	715
Kelly	Christian	L. & N. R. R.	681
Kelsey	Caldwell	U. S. B. M.	403
Kennebec	Franklin	U. S. B. M. R. R. Station	507
Kenney	Scott	L. S. R. R.	832
Kenova	W. Va.	N. & W. R. R.	589
Kenton Heights	Kenton	Q. & C. R. R.	830
Kentucky River	Carroll	L. W. at Carrollton	413
Kentucky River	Carroll	L. W. at Pool 1	430
Kentucky River	Owen	L. W. at Pool 2	443
Kentucky River	Franklin	L. W. at Pool 3	446
Kentucky River	Franklin	L. W. at Frankfort	470
Kentucky River	Anderson	L. W. at Tyrone	484
Kentucky River	Jessamine	L. W. at High Bridge	492
Kentucky River	Jessamine	L. W. at Hickman Bridge	503
Kentucky River	Fayette	L. W. at Clay's Ferry	533

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Kentucky River	Clark	L. W. at Boonesboro	538
Kentucky River	Clark	L. W. at mouth of Red River	548
Kentucky River	Estill	L. W. at Irvine	571
Kentucky River	Lee	L. W. at Beattyville	618
Kermit	W. Va.	N. & W. R. R.	629
Kevil	Ballard	I. C. R. R.	439
Kilgore	Carter	U. S. B. M.	634
Kings Mountain	Lincoln	Q. & C. R. R.	1,168
Kinkaid	Scott	Q. & C. R. R.	862
Kirk	Breckenridge	L. H. & St. L. R R.	689
Kirkmansville	Todd	U. S. B. M.	476
Kirkwood	Mercer	U. S B. M.	852
Kirkwood Springs	Hopkins	U. S. B. M.	440
Kise	Lawrence	C. & O. R. R.	595
Kiserton	Bourbon	L. & N. R. R.	798
Kite	Knott	U. S. B. M.	879
Knob Lick	Nelson	L. & N. R. R.	900
Knottsville	Daviess	U. S. B. M.	559
Kona	Letcher	L. & E. R. R.	1,257
Krypton	Perry	L. & E. R. R.	805
Kuttawa	Lyon	I. C. R. R.	436
Lackey	Floyd	U. S. B. M.	695
Lagrange	Oldham	L. & N. R. R.	841
Lair	Harrison	L. & N. R. R.	743
Laketon	Carlisle	M. & O. R. R.	315
Lancaster C. H.	Garrard	U. S. B. M.	1,032
Langford	Rockcastle	L. & N. R. R.	906
Langley	Floyd	U. S. B. M.	673
Latonia	Kenton	L. & N. R. R.	537
Lawrenceburg	Anderson	U. S. B. M. C. H.	788
Layman P. O.	Harlan	U. S. B. M.	1,116
Lebanon	Marion	L. & N. R. R.	754
Lebanon Church	Franklin	U. S. B. M.	889
Lebanon Junction	Bullitt	L. & N. R. R.	429
Leburn	Knott	U. S. B. M.	1,045
Leitchfield	Grayson	I. C. R. R.	635
L. & E. Junction	Clark	U. S. B. M. L. & E. Station	929
L. & E. Tunnel	Clark	L. & E. R. R.	1,006
Leon	Carter	C. & O. R. R.	598
Levingood	Pendleton	L. & N. R. R.	629
Lewis	Daviess	L. & N. R. R.	403
Lewisburg	Logan	U. S. B. M.	496
Lewisburg	Mason	L. & N. R. R.	466
Lewisport	Hancock	L. W. in Ohio River	333
Lewisport	Hancock	U. S. B. M.	393
Lexington	Fayette	U. S. B. M.	957
Licking River	Kenton	L. W. at Covington	432
Licking River	Kenton	L. W. at De Coursey	446
Licking River	Kenton	L. W. at Visalia	453
Licking River	Pendleton	L. W. at mouth of South Fork	512
Licking River	Pendleton	L. W. at mouth of North Fork	536
Licking River	Robertson	L. W. at Claysville	544
Licking River	Nicholas	L. W. at Lower Blue Lick	566

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Licking River	Nicholas	L. W. at mouth of Big Fleming	577
Licking River	Nicholas	L. W. at mouth of Upper Blue Lick	592
Licking River	Bath	L. W. at mouth of Flat Creek	597
Licking River	Bath	L. W. at mouth of Slate Creek	623
Licking River	Bath	L. W. at mouth of Salt Creek	644
Licking River	Bath	L. W. at mouth of Beaver	676
Licking River	Morgan	L. W. at mouth of Elk Fork	733
Licking River	Morgan	L. W. at West Liberty	742
Licking River	Morgan	L. W. at mouth of White Oak	766
Licking River	Morgan	L. W. at mouth at Rockhouse	776
Licking River	Magoffin	L. W. at mouth of Johnson's Fork	806
Licking River	Magoffin	L. W. at mouth of Middle Fork	820
Licking River	Magoffin	L. W. at Salyersville	840
Lily	Laurel	L. & N. R. R.	1,072
Limeville	Greenup	C. & O. R. R.	531
Lisman	Webster	U. S. B M.	410
Little Cypress	Marshall	I. C. R. R.	352
Little Muddy	Butler	U. S. B. M.	468
Livermore	McLean	U. S. B. M.	401
Livia	McLean	L. & N. R. R.	422
Livingston	Crittenden	U. S. B. M. R. R. Station	370
Livingston	Rockcastle	L. & N. R. R.	858
Lockport	Henry	U. S. B. M.	450
Lockwood	Boyd	C. & O. R. R.	546
Lodiburg	Breckenridge	L. H. & St. L. R. R.	485
Logan	Shelby	L. & N. R. R.	613
Logansport	Butler	U. S. B. M.	471
Lombard	Powell	U. S. B. M. L & E. Station	681
London	Laurel	L. & N. R. R.	1,209
Long	Warren	U. S. B. M.	618
Long Branch	Meade	L. H. & St. L. R. R.	417
Long Fork	Pike	U. S. B. M.	1,019
Long Grove	Hardin	I. C. R. R.	605
Long Run	Jefferson	U. S. B. M. L. & N. Station	630
Longview	Jefferson	U. S. B. M.	445
Lookout	Pike	U. S. B. M.	968
Loretto	Marion	L. & N. R. R.	711
Lost Creek	Breathitt	U. S. B. M.	751
Louisa	Lawrence	L. W. in Big Sandy River	526
Louisa	Lawrence	C. & O. R. R.	587
Louisville	Jefferson	L. W. above Falls	386
Louisville	Jefferson	Weather Bureau	525
Lovell	Knox	L. & N. R. R.	982
Lowell	Garrard	L. & N. R. R.	799
Ludlow	Kenton	Q. & C. R. R.	535
Luzon	Webster	U. S. B. M.	455
Lyndon	Jefferson	U. S. B. M.	561
Lynn Camp	Laurel	L. & N. R. R.	1,045
Lyonia	Hancock	U. S. B. M.	514
McBrayer	Anderson	U. S. B. M.	832
McClain	Henderson	I. C. R. R.	378

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
McDonald Ferry	Franklin	U. S. B. M.	503
McDowell	Floyd	U. S. B. M.	691
McGowan	Caldwell	U. S. B. M.	484
McGowan Ferry	Woodford	U. S. B. M.	656
McHenry	Ohio	U. S B. M.	427
McKinley	McLean	U. S. B. M.	381
McKinney	Lincoln	Q. & C. R. R.	1,008
McLeod	Logan	L. & N. R. R.	610
McNary	Muhlenberg	I. C. R. R.	427
McNeal	Boyd	U. S. B. M.	593
Macedonia	Christian	U. S. B. M.	520
Madisonville	Hopkins	U. S. B. M.	470
Magan	Ohio	U. S. B. M.	617
Mahan	Whitley	L. & N. R. R.	899
Major	Henderson	I. C. R. R.	378
Manchester	Lewis	L. W. in Ohio River	451
Manchester	Lewis	C. & O. R. R.	525
Manitou	Hopkins	U. S. B. M.	427
Mannington	Christian	U. S. B. M.	423
Marcellus	Garrard	U. S. B. M.	916
Maretburg	Rockcastle	L. & N. R. R.	1,165
Marion	Crittenden	U. S. B. M. R. R. Station	583
Marksbury	Garrard	U. S. B. M.	981
Marrowbone	Pike	C. & O R. R.	719
Marvin	Lawrence	U. S. B. M.	604
Mason	Grant	Q. & C. R. R.	924
Masonville	Christian	T. C. R. R.	557
Massack	McCracken	U. S. B. M.	450
Masu	Perry	L. & E. R. R.	905
Matewan	W. Va.	N. & W. R. R.	699
Mattie	Knott	U. S. B. M.	1,334
Mattingly	Breckenridge	L. H. & St. L. R. R.	343
Maurice	Kenton	L. & N. R. R.	498
Mavity	Boyd	U. S. B. M.	612
Maxon	McCracken	I. C. R. R.	365
Maxwell	Ohio	U. S. B. M.	438
Mayde	Madison	L. & N. R. R.	936
Mayfield	Graves	I. C. R. R.	421
Mayking	Letcher	L. & E. R. R.	1,203
Mayo	Mercer	U. S. B. M.	905
Maysville	Mason	L. W. in Ohio River	448
Maysville	Mason	C. & O. R. R.	507
Maywood	Lincoln	L. & N. R. R.	1,015
Meads	Boyd	C. & O. R. R.	590
Meadow Lawn	Jefferson	U. S. B. M.	446
Means Tunnel	Carter	C. & O. R. R.	770
Meek	Johnson	C. & O. R. R.	609
Memphis Junction	Warren	L. & N. R. R.	533
Mentor	Campbell	C. & O. R. R.	500
Mercer	Muhlenberg	I. C. R. R.	471
Mexico	Crittenden	U. S. B. M. R. R. Station	494
Middlesboro	Bell	U. S. B. M. at R. R. Station	1,139
Middletown	Jefferson	U. S. B. M.	722

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Midway	Woodford	U. S. B. M on P. O.	820
Milledgeville	Lincoln	U. S. B. M.	1,035
Mill Springs	Wayne	U. S. B. M.	844
Millwood	Grayson	I. C. R. R.	603
Mississippi River	Fulton	L. W. at Hickman	256
Mississippi River	Hickman	L. W. at Columbus	270
Mississippi River	Ballard	L. W. at mouth of Ohio River	272
Mitchellsburg	Boyle	U. S. B. M.	1,006
Monica	Lee	U. S. B. M. L. & E. Station	683
Monterey	Owen	L. W. in Kentucky River	442
Monterey	Owen	U. S. B. M.	543
Monticello	Wayne	U. S. B. M. on C. H.	926
Montrose	Fayette	U. S. B. M. L. & E. Station	934
Moore	Anderson	L. S. R. R.	729
Mooresville	Washington	L. & N. R. R.	650
Moran's Summit	Madison	L. & N. R. R.	964
Morehead	Rowan	C. & O. R. R.	712
Moreland	Lincoln	U. S. B. M.	1,120
Morgan	Pendleton	L. & N. R. R.	610
Morganfield	Union	U. S. B. M. at C. H.	439
Morgantown	Butler	U. S. B. M.	573
Morton's Gap	Hopkins	U. S. B. M.	451
Mortonville P. O.	Woodford	U. S. B. M.	790
Moscow	Hickman	M. & O. R. R.	313
Moseleyville	Daviess	U. S. B. M.	386
Motherhead Ford	Bullitt	U. S. B. M.	435
Mt. Guthrie	Rockcastle	L. & N. R. R.	1,121
Mt. Savage	Carter	U. S. B. M.	610
Mt. Sterling	Montgomery	C. & O. R. R.	934
Mt. Vernon	Rockcastle	L. & N. R. R.	1,113
Mt. Washington	Bullitt	U. S. B. M.	688
Muldraugh	Meade	I. C. R. R.	740
Muldraugh Hill	Hardin	L. & N. Tunnel	767
Muldraugh Hill	Marion	L. & N. R. R.	1,160
Mullins	Rockcastle	L. & N. R. R.	904
Mundys	Woodford	U. S. B. M.	500
Munfordville	Hart	Court House	571
Murray	Calloway	N. C. & St. L. R. R.	480
Music	Carter	U. S. B. M.	702
Myers	Nicholas	L. & N. R. R.	613
Myra	Pike	U. S. B. M.	977
Natural Bridge	Powell	U. S. B. M. L. & E. Station	763
Naugatuck	W. Va.	N. & W. R. R.	637
Nazareth	Nelson	L. & N. R. R.	693
Neal	W. Va.	N. & W. R. R.	569
Nealy	Knott	U. S. B. M.	1,129
Nebo	Hopkins	U. S. B. M.	409
Ned	Breathitt	U. S. B. M. at P. O.	808
Nelson	Muhlenberg	U. S. B. M.	420
Nelsonville	Nelson	L. & N. R. R.	434
Neon	Letcher	L. & E. R. R.	1,279
Nevins	Anderson	L. S. R. R.	770
New Haven	Nelson	L. & N. R. R.	444

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
New Hope	Nelson	L. & N. R. R.	488
Newman	Daviess	U. S. B. M.	382
Newport	Campbell	C. & O. R. R.	536
New Richmond	Campbell	C. & O. R. R.	496
Niagara	Henderson		477
Nicholasville	Jessamine	B. M. in Court House	947
Nicholasville	Jessamine	U. S. B. M.	993
Nolan	W. Va.	N. & W. R. R.	651
Nolin	Hardin	L. & N. R. R.	660
Nonesuch	Woodford	U. S. B. M.	812
Normal	Boyd	C. & O. R. R.	539
North Fork	Boyle	L. & N. R. R.	934
North Siding	McLean	L. & N. R. R.	394
Nortonville	Hopkins	U. S. B. M.	408
Norwood	Pulaski	Q. & C. R. R.	1,122
Nuckols	McLean	U. S. B. M.	400
Nunns	Crittenden	U. S. B. M. R. R. Station	375
Oakdale	Breathitt	U. S. B. M. L. & E. Station	791
Oakland	Warren	L. & N. R. R.	531
Oak Ridge	Daviess	I. C. R. R.	458
Oaks	McCracken	N. C. & St. L. R. R.	348
Oakton	Hickman	M & O. R. R.	321
O'Bannon	Jefferson	U. S. B. M.	765
Ohio River		L. W. at mouth	272
Ohio River	McCracken	L. W. at Paducah	286
Ohio River		L. W. at Shawneetown	301
Ohio River	Union	L. W. at Raleigh	302
Ohio River	Union	L. W. at Uniontown	306
Ohio River		L. W at Mt. Vernon	308
Ohio River	Henderson	L. W. at Henderson	317
Ohio River	Daviess	L. W. at Owensboro	328
Ohio River		L. W. at Rockport	330
Ohio River	Hancock	L. W. at Lewisport	333
Ohio River		L. W. at Troy	335
Ohio River	Breckenridge	L. W. at Cloverport	340
Ohio River	Meade	L. W. at Concordia	346
Ohio River	Meade	L. W. at Brandenburg	356
Ohio River	Jefferson	L. W. at Louisville	386
Ohio River	Jefferson	L. W. at Bethlehem	399
Ohio River		L. W. at Madison	401
Ohio River		L. W. at Vevay	408
Ohio River	Gallatin	L. W. at Warsaw	411
Ohio River	Carroll	L. W. at Carrollton	413
Ohio River		L. W. at Cincinnati	431
Ohio River	Bracken	L. W. at Augusta	444
Ohio River	Mason	L. W. at Maysville	448
Ohio River		L. W. at Manchester	451
Ohio River	Lewis	L. W. at Quincy	464
Ohio River	Greenup	L. W. at Greenup	478
Ohio River	Boyd	L. W. at Catlettsburg	498
Oil City	Barren	G. R. R.	610
Oil Valley	Wayne	U. S. B. M.	966
O. & K. Junction	Breathitt	U. S. B. M. L. & E. Station	737

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Oklahoma	Daviess	U. S. B. M.	440
Okolona	Jefferson	U. S. B. M.	470
Olaton	Ohio	I. C. R. R.	430
Old Deposit	Jefferson	L. & N. R. R.	453
Oldtown	Greenup	U. S. B. M.	559
Olive Hill	Carter	C. & O. R. R.	752
Olmstead	Logan	L. & N. R. R.	563
Olympia	Bath	C. & O. R. R.	751
Oneonta	Campbell	C. & O. R. R.	501
Ono	Russell	U. S. B M.	976
Onton	Webster	U. S. B. M.	479
Ore Knob	Pike	U. S. B. M.	1,188
Orell	Jefferson	L. & N. R. R.	412
Ortiz	Webster	U. S. B. M.	528
Orville	Henry	U. S. B. M.	589
Otter Cr. Sta.	Hardin	I. C. R. R.	664
Otter Pond	Caldwell	U. S. B. M.	544
Ottusville	Franklin	U. S. B. M.	529
Owensboro	Daviess	L. W. in Ohio River	328
Owensboro	Daviess	U. S. B. M. C. H.	396
Pactolus	Carter	U. S. B. M.	580
Paducah	McCracken	L. W. in Ohio River	286
Paducah	McCracken	I. C. R. R.	341
Paint Lick	Garrard	L. & N. R R.	794
Paintsville	Johnson	C. & O. R. R.	620
Palace P. O.	Wayne	U. S. B. M.	649
Pansy Creek	Harlan	U. S. B. M.	1,328
Panther	Daviess	U. S. B. M.	473
Panther Creek	Daviess	L. & N. R. R.	377
Paradise	Muhlenberg	U. S. B. M.	408
Paris	Bourbon	L. & N. R. R.	826
Paris Junction	Bourbon	L. & N. R. R.	863
Parksville	Boyle	L. & N. R. R.	1,052
Pauline	Logan	U. S. B. M.	571
Paynes Depot	Scott	U. S. B. M.	847
Paynes Gap	Letcher	U. S. B. M.	1,873
Peach Orchard	Lawrence	C. & O. R. R.	500
Peaks	Scott	S. R. R.	884
Pellville	Hancock	U. S. B. M.	531
Pembroke	Christian	L. & N. R. R.	562
Pendleton	Henry	L. & N. R. R.	830
Penick	Marion	L. & N. R. R.	930
Penrod	Muhlenberg	U. S. B. M.	427
Perryville	Boyle	U. S. B. M.	851
Petersburg	Christian	L. & N. R. R.	400
Petersburg	Jefferson	U. S. B. M.	497
Petrie	Hancock	L. H. & St. L. R. R.	358
Pettit	Daviess	U. S B. M.	389
Pewee Valley	Oldham	U. S. B. M.	784
Philips Store	Muhlenberg	U. S. B. M.	400
Phillipsburg	Marion	L. & N. R. R.	704
Philpot	Daviess	U. S. B. M.	399
Pierce	Breckenridge	L. H. & St. L. R. R.	407

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Pierceton	Hopkins	T. C. R. R.	594
Pikeville	Pike	C. & O. R. R.	680
Pilot Oak	Graves	Weather Bureau	411
Pinckard	Woodford	U. S. B. M.	824
Pine Grove	Clark	C. & O. R. R.	960
Pine Hill	Rockcastle	L. & N. R. R.	966
Pine Knot	McCreary	Q. & C. R. R.	1,410
Pineville	Bell	U. S. B. M.	1,062
Piney	Crittenden	U. S. B. M.	409
Pink	Jessamine	U. S. B. M.	818
Pinkard	Woodford	U. S. B. M.	824
Pisgah	Woodford	U. S. B. M.	863
Pittsburg	Laurel	L. & N. R. R.	1,135
Pleasant Hill	Mercer	U. S. B. M.	932
Pleasant Home	Owen	U. S. B. M.	887
Pleasant Valley	Rockcastle	L. & N. R. R.	1,110
Pleasant View	Whitley	L. & N. R. R.	971
Pleasure Ridge Park	Jefferson	I. C. R. R.	447
Pleasureville	Henry	L. & N. R. R.	882
Poindexter	Harrison	L. & N. R. R.	717
Point Burnside	Pulaski	Q. & C. R. R.	778
Point Leavell	Garrard	L. & N. R. R.	884
Pond Creek	Pike	C. & O. R. R.	742
Poole	Webster	U. S. B. M.	499
Potter	Lawrence	C. & O. R. R.	573
Potters Gap	Letcher	U. S. B. M.	1,688
Pound Gap	Letcher	U. S. B. M.	2,512
Poverty	McLean	U. S. B. M.	391
Powers	Daviess	L. H. & St. L. R. R.	362
Pratt	Webster	U. S. B. M.	502
Preachersville	Lincoln	U. S. B. M.	998
Preston	Bath	C. & O. R. R.	742
Prestonia	Jefferson	U. S. B. M.	511
Prestonsburg	Floyd	L. W. in Big Sandy River	606
Prestonsburg	Floyd	U. S. B. M. C. & O. Station	637
Prewitt	Montgomery	C. & O. R. R.	1,054
Prichard	W. Va.	N. & W. R. R.	569
Princess	Boyd	C. & O. R. R.	632
Princeton	Caldwell	U. S. B. M. R. R. Station	484
Prospect	Jefferson	U. S. B. M.	484
Prosperity	Lawrence	U. S. B. M.	632
Providence	Webster	U. S. B. M.	453
Pryors	Graves	I. C. R. R.	420
Pryorsburg	Graves	I. C. R. R.	411
Pulaski	Pulaski	Q. & C. R. R.	1,120
Quality	Butler	U. S. B. M. at P. O.	503
Quarry Switch	Bullitt	L. & N. R. R.	463
Quicksand	Knott	U. S. B. M.	1,700
Quincy	Lewis	L. W. in Ohio River	464
Quincy	Lewis	C. & O. R. R.	543
Quinn	Caldwell	U. S. B. M.	530
Railey	Woodford	S. R. R.	834
Raleigh	Union	L. W. in Ohio River	302

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Ralph	Ohio	S. B. M.	430
Rankin	Henderson	L. & N. R. R.	372
Raven	Knott	U. S. B. M.	749
Red Hill	Christian	U. S. B. M.	450
Red Hill	Hardin	I. C. R. R.	751
Red House	Madison	L. & N R. R.	710
Red Oak	Logan	L. & N. R. R.	595
Red River	Logan	L. & N. R. R.	522
Reed	Henderson	U. S. B. M.	379
Renick	Marion	L. & N. R. R.	927
Repton	Crittenden	U. S. B. M. R. R. Station	485
Republican	Knott	U. S. B. M.	804
Reynolds Station	Ohio	U. S. B. M.	497
Ricedale	Muhlenberg	L. & N. R. R.	387
Richardson	Lawrence	C. & O. R. R.	599
Richardson	Lawrence	L. W. in Big Sandy	549
Richardsville	Warren	U. S. B. M.	686
Richland	Hopkins	U. S. B. M.	431
Richmond	Madison	L. & N. R. R.	926
Rich Pond	Warren	L. & N. R. R.	564
Richwood	Boone	Q. & C. R. R.	924
Riley	Marion	L. & N. R. R.	914
Rineyville	Hardin	I. C. R. R.	808
Riverside	Clark	L. & N. R. R.	645
Riverside	Jefferson	I. C. R. R.	446
Riverton	Greenup	C. & O. R. R.	534
Roachville	Green	L. W. in Green River	544
Robard	Henderson	U. S. B. M.	425
Robinson	Harrison	L. & N. R. R.	674
Rochester	Butler	U. S. B. M.	451
Rockfield	Warren	L. & N. R. R.	568
Rock Haven	Meade	L. H. & St. L. R. R.	412
Rockhold	Whitley	L. & N. R. R.	955
Rockhouse	Pike	C. & O. R. R.	880
Rockland	Warren	U. S. B. M.	664
Rockport	Ohio	U. S. B. M.	436
Rock Springs	Henderson	U. S. B. M.	486
Rock Vale	Breckenridge	L. H. & St. L. R. R.	435
Rocky Hill	Edmonson	L. & N. R. R.	596
Rogers Gap	Scott	Q. & C. R. R.	913
Rosine	Ohio	U. S. B. M.	564
Ross	Campbell	C. & O. R. R.	494
Rosslyn	Powell	U. S. B. M. L. & E. Station	668
Rothwell	Menifee	C. & O. R. R.	993
Rough River	Ohio	Lock 1. Top of wall	381
Roumine	Taylor	Kentucky Geological Survey	784
Rowland	Lincoln	L. & N. R. R.	844
Rowletts	Hart	L. & N. R. R.	610
Roxana	Letcher	L. & E. R. R.	1,039
Rufus	Caldwell	U. S. B. M.	425
Rugless	Lewis	C. & O. R. R.	703
Rumsey	McLean		384
Rush	Boyd	U. S. B. M.	639

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Russell	Greenup	C. & O. R. R.	549
Russellville	Logan	L. & N. R. R.	534
Ruth	Breckenridge	L. H. & St. L. R. R.	493
Sacramento	McLean	U. S. B. M.	497
Sadieville	Scott	Q & C. R. R.	857
Saffell	Franklin	U. S. B. M.	890
Saffells	Anderson	S. R. R.	754
Salmons	Simpson	L. & N. R. R.	677
Salt Lick	Bath	C. & O. R. R.	656
Saltpetre	W. Va.	N. & W. R. R.	584
Salvisa	Mercer	U. S. B. M.	808
Salyersville	Magoffin	L. W. in Licking River	840
Sample	Breckenridge	L. H. & St. L. R. R.	392
Samuel Hill	Bullitt	U. S. B. M.	838
Samuels	Nelson	L. & N. R. R.	652
Sanders	Carroll	L. & N. R. R.	488
Sands	W. Va.	N. & W. R. R.	737
Savage Branch	Boyd	C. & O. R. R.	547
Saxton	Whitley	L. & N. R. R.	966
Sayers	Nelson	L. & N. R. R.	674
Science Hill	Pulaski	Q. & C. R. R.	1,115
Scott	Shelby	U. S. B. M. R. R. Station	744
Scottsburg	Caldwell	U. S. B. M.	521
Scuffletown	Henderson	U. S. B. M.	375
Seatonsville	Jefferson	U. S. B. M.	500
Sebree	Webster	U. S. B. M.	500
Shady Grove	Crittenden	U. S. B. M.	426
Shannondale	Fayette	U. S. B. M.	888
Shawhan	Bourbon	L. & N. R. R.	825
Shearer	Madison	L. & N. R. R.	615
Shelby	Boyle	U. S. B. M.	991
Shelby	Pike	C. & O. R. R.	705
Shelby Gap	Pike		1,431
Shelby Junction	Jefferson	L. & N. R. R.	696
Shelbyville	Shelby	U. S. B. M. C. H.	760
Shepherdsville	Bullitt	U. S. B. M. C. H.	446
Sherman	Grant	Q. & C. R. R.	924
Shively	Jefferson	U. S. B. M.	458
Silver Creek Sta	Madison	L. & N. R. R.	804
Simpsonville	Shelby	U. S. B. M. R. R. Station	796
Sinks	Rockcastle	L. & N. R. R.	906
Skillman	Hancock	L. H. & St. L. R. R.	387
Skylight	Oldham	U. S. B. M.	704
Slaughtersville	Webster	U. S. B. M.	403
Sloans Valley	McCreary	Q. & C. R. R.	912
Smithfield	Henry	L. & N. R. R.	875
Smithland	Livingston	L. W. in Ohio River	286
Smith's Grove	Warren	L. & N. R. R.	607
Smyrna	Jefferson	U. S. B. M.	632
Snider	Spencer	L. & N. R. R.	1,004
Soldier	Carter	C. & O. R. R.	950
Somerset	Pulaski	B. M .on Cumberland Hotel	879
Sonora	Hardin	L. & N. R. R.	699

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Sorgho	Daviess	U. S. B. M.	389
South Carrollton	Muhlenberg	U. S. B. M.	456
South Columbus	Hickman	M. & O. R. R.	354
South Covington	Kenton	L. & N. R. R.	529
South Elkhorn	Fayette	U. S. B. M.	957
South Fork	Lincoln	Weather Bureau	981
South Hill	Butler	U. S. B. M.	546
South Louisville	Jefferson	L. & N. R. R.	462
South Park	Jefferson	U. S. B. M.	478
South Portsmouth	Greenup	C. & O. R. R.	529
South Ripley	Mason	C. & O. R. R.	507
South Union	Logan	L. & N. R. R.	579
Sparta	Gallatin	L. & N. R. R.	497
Specht	Pike	U. S. B. M.	1,207
Spencer	Montgomery	C. & O. R. R.	783
Spider	Knott	U. S. B. M.	1,050
Spottsville	Henderson	U. S. B. M.	365
Sprigg	W. Va.	N. & W. R. R.	690
Springdale	Jefferson	U. S. B. M.	620
Springdale	Mason	C. & O. R. R.	509
Springfield	Washington	L. & N. R. R.	738
Spring Lick	Grayson	I. C. R. R.	387
Spring Station	Woodford	U. S. B. M.	816
Spurlington	Taylor	L. & N. R. R.	981
St. Charles	Hopkins	U. S. B. M.	427
St. Helens	Lee	U. S. B. M. L. & E. Station	674
St. John	Hardin	Weather Bureau	760
St. Joseph	Daviess	U. S. B. M.	420
St. Mary	Marion	L. & N. R. R.	733
St. Matthews	Jefferson	U. S. B. M.	550
St. Vincent	Union	I. C. R. R.	413
Stamping Ground	Scott	U. S. B. M. R. R. Station	799
Stanford	Lincoln	U. S. B. M. C. H.	912
Stanhope	Webster	U. S. B. M.	468
Stanley	Daviess	U. S. B. M.	385
Stanton	Powell	U. S. B. M. L. & E. Station	662
State Line	Christian	L. & N. R. R.	535
State Line	Whitley	Q. & C. R. R.	1,350
Stedman	Franklin	U. S. B. M. R. R. Station	711
Stephensburg	Hardin	I. C. R. R.	611
Stephensport	Breckenridge	L. W. in Ohio River	340
Stophensport	Breckenridge	L. H. & St. L. R. R.	390
Stepstone	Montgomery	C. & O. R. R.	777
Steubenville	Wayne		887
Stine	Jefferson	L. S. R. R.	484
Stithton	Hardin	I. C. R. R.	686
Stone Coal	Knott	U. S. B. M.	696
Strawberry	Jefferson	L. & N. R. R.	432
Stroud	Muhlenberg	L. & N. R. R.	380
Strunk	McCreary	Q. & C. R. R.	1,397
Sturgis	Union	U. S. B. M. R. R. Station	375
Sullivan	Union	U. S. B. M.	396
Sulphur	Henry	L. & N. R. R.	683

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Sulphur Springs	Ohio	U. S. B. M.	418
Summit	Boyd	C. & O. R. R.	664
Summit	Mason	L. & N. R. R.	905
Summit	McCreary	Q. & C. R. R.	1,263
Sunnydale	Ohio	U. S. B. M.	427
Sutherland	Daviess	U. S. B. M.	400
Sutton Knob	Whitley	U. S. B. M.	1,515
Swallowfield	Franklin	U. S. B. M.	527
Sweeney	Garrard	U. S. B. M.	1,024
Switzer	Franklin	U. S. B. M. R. R. Station	725
Tackitt's Mill	Owen	U. S. B. M.	641
Taffy	Ohio	U. S. B. M.	480
Talbott	Bourbon	L. & N. R. R.	808
Tallega	Lee	U. S. B. M. L. & E. Station	689
Talmage	Mercer	U. S. B. M.	821
Tannery	Lewis	C. & O. R. R.	552
Tateville	McCreary	Q. & C. R. R.	877
Taylor Mines	Ohio	U. S. B. M.	500
Taylorsville	Spencer	U. S. B. M. on C. H.	490
Teresita P. O.	Owen	U. S. B. M.	637
Terrapin	Mercer	U. S. B. M.	876
Thacker	W. Va.	N. & W. R. R.	716
The Forks	Pike	C. & O. R. R.	710
Thompson's	Montgomery	C. & O. R. R.	1,037
Thompson	Union	I. C. R. R.	408
Thompsonville	Christian	T. C. R. R.	542
Threlkel	Butler	U. S. B. M.	430
Thurman	Hickman	I. C. R. R.	322
Tichenor	McLean	L. & N. R. R.	383
Tilden	Webster	U. S. B. M.	425
Tip Top	Hardin	I. C. R. R.	760
Topeka Crossroads	Union	U. S. B. M.	430
Torchlight	Lawrence	U. S. B. M.	538
Torrent	Wolfe	U. S. B. M. L. & E. Station	939
Tradewater	Hopkins	I. C. R. R.	456
Trenton	Todd	L. & N. R. R.	531
Tribune	Crittenden	U. S. B. M.	431
Triplett Tunnel	Carter	C. & O. R. R.	1,002
Troy	Woodford	U. S. B. M.	828
Tucker	Jefferson	S. R. R.	719
Tunnel Hill	Henderson	U. S. B. M.	443
Tunnel Hill	Hardin	L. & N. R. R.	767
Turners	Henry	L. & N. R. R.	740
Twin Tunnels	Muhlenberg	U. S. B. M. L. & N. Station	501
Typo	Perry	L. & E. R. R.	840
Tyrone	Anderson	L. W. in Kentucky River	483
Tyrone	Anderson	U. S. B. M.	738
Ulvan	Perry	L. & E. R. R.	951
Uma	Pendleton	L. & N. R. R.	597
Union Mills	Jessamine	U. S. B. M.	939
Uniontown	Union	L. W. in Ohio River	306
Uniontown	Union	I. C. R. R.	354
Upland	McCreary	Q. & C. R. R.	1,253

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Upper Bruce	Lewis	C. & O. R. R.	553
Upton	Hardin	L. & N. R. R.	724
Utica	Daviess	U. S. B. M.	417
U. Z.	Letcher	L. & E. R. R.	1,083
Vaden	Oldham	L. & N. R. R.	850
Valley Hill	Washington	L. & N. R. R.	572
Valley Station	Jefferson	U. S. B. M.	452
Vanarsdell	Mercer	U. S. B. M.	788
Vanceburg	Lewis	C. & O. R. R.	523
Vanderburg	Webster	U. S. B. M.	580
Van Meter	Fayette	L. S. R. R.	880
Veazey	Hopkins	U. S. B. M.	564
Veechdale	Shelby	L. S. R. R.	742
Verona	Boone	L. & N. R. R.	862
Versailles	Woodford	U. S. B. M.	923
Vest	Knott	U. S. B. M.	1,044
Vine Grove	Hardin	I. C. R. R.	721
Viola	Graves	I. C. R. R.	400
Virden	Powell	U. S. B. M. L & E. Station	660
Virgie	Pike	U. S. B. M.	837
Visalia	Kenton	L. W. in Licking River	453
Waddy	Shelby	S. R. R.	854
Wagon Ford	Crittenden	U. S. B. M.	353
Waitman	Hancock	L. H. & St. L. R. R.	344
Walbridge	Lawrence	U. S. B. M.	588
Wallace	Woodford	L. S. R. R.	814
Walnut	Knott	U. S. B. M.	2,004
Walnut Grove	Caldwell	U. S. B. M.	449
Walnut Hill School	Caldwell	U. S. B. M.	588
Walton	Boone	Q. & C. R. R.	912
Wanamaker	Webster	U. S. B. M.	445
Wards	Carter	C. & O. R. R.	669
Warfield	Martin	L. W. in Big Sandy	587
Warsaw	Gallatin	L. W. in Ohio River	411
Wasioto	Bell	U. S. B. M. L. & N. Station	1,025
Waterford	Spencer	U. S. B. M.	468
Water Valley	Graves	I. C. R. R.	386
Water Works	Campbell	C. & O. R. R.	498
Waverly	Union	I. C. R. R.	408
Waynesburg	Lincoln	Q. & C. R. R.	1,215
Weaverton	Henderson	I. C. R. R.	380
Webb	W. Va.	N. & W. R. R.	601
Webbville	Lawrence	U. S. B. M.	648
Webster	Breckinridge	L. H. & St. L. R. R.	542
Weir	Muhlenberg	U. S. B. M.	629
Welborn	Muhlenberg	L. & N. R. R.	486
Wellsburg	Bracken	C. & O. R. R.	501
West Clifty	Grayson	I. C. R. R.	631
Westerfield	Ohio	U. S. B. M.	464
West Liberty	Morgan	L. W. in Licking River	742
West Louisville	Daviess	U. S. B. M.	462
West Point	Hardin	U. S. B. M.	441
Westport	Oldham	U. S. B. M.	487

Elevation Above Sea of Points in Kentucky—Continued.

Place.	County.	Station.	Elevation.
Wetwoods	Jefferson	U. S. B. M.	473
Whalen P. O.	Daviess	U. S. B. M.	432
Wheatcroft	Webster	U. S. B. M.	376
Whick	Breathitt	L. & E. R. R.	776
Whippoorwill	Logan	L. & N. R. R.	539
Whitefield	Bullitt	U. S. B. M.	729
White House	Johnson	C. & O. R. R.	605
White Oak	Pulaski	Q. & C. R. R.	956
White Plains	Hopkins	I. C. R. R.	430
White's Station	Madison	L. & N. R. R.	903
Whitesburg	Letcher	L. & E. R. R.	1,146
White Sulphur	Caldwell	U. S. B. M. R. R. Station	501
White Sulphur	Scott	U. S. B. M.	873
Whitesville	Daviess	U. S. B. M.	506
Whitewood	Green	L. & N. R. R.	570
Whitley	McCreary	Q. & C. R. R.	1,332
Whitney	Scott	Q. & C. R. R.	857
Wiborg	McCreary	Q. & C. R. R.	1,280
Wickliffe	Ballard	I. C. R. R.	322
Wildie	Rockcastle	L. & N. R. R.	928
Wilders	Campbell	L. & N. R. R.	492
Willard	Carter	U. S. B. M.	625
Williamsburg	Whitley	L. & N. R. R.	939
Williamson	W. Va.	N. & W. R. R.	665
Williamstown	Grant	Q. C. R. R.	943
Wilmore	Jessamine	U. S. B. M.	882
Wilson	Henderson	I. C. R. R.	377
Wilson Bridge	Hopkins	U. S. B. M.	372
Wilsonville	Spencer	U. S. B. M.	643
Winchester	Clark	U. S. B. M. L. & E. Station	981
Windom	Jesamine	Q. & C. R. R.	1,032
Wingo	Graves	I. C. R. R.	466
Wolf Lick	Logan	L. & N. R. R.	401
Woodbine	Whitley	L. & N. R. R.	1,080
Woodburn	Warren	L. & N. R. R.	610
Woodland	Hart	L. & N. R. R.	623
Woodlawn	Jefferson	L. & N. R. R.	509
Woods	Floyd	U. S. B. M.	643
Woodville	Christian	I. C. R. R.	512
Worthington	Henderson	L. H. & St. L. R. R.	382
Worthington	Jefferson	U. S. B. M.	695
Worthville	Carroll	L. & N. R. R.	478
Wrights	Taylor	L. & N. R. R.	616
Wurtland	Greenup	C. & O. R. R.	539
Wyandotte	Clark	U. S. B. M. L. & E. Station	990
Wyman	McLean	U. S. B. M.	484
Wynn Bridge	Union	U. S. B. M.	364
Wysox	Ohio	U. S. B. M.	401
Yatesville	Lawrence	U. S. B. M.	582
Yeager	Pike	C. & O. R. R.	730
Yerkes	Perry	L. & E. R. R.	823
Youngs High Bridge	Anderson	S. R. R.	706
Zelda P. O.	Lawrence	U. S. B. M.	567
Zion	Henderson	U. S. B. M.	436
Zoneton	Bullitt	U. S. B. M.	485

ASTRONOMICAL STATIONS IN KENTUCKY.

Place.	County	Latitude			Longitude		
Alpha	Clinton	36°	46′	01.4″	85°	00′	34.6″
Anchorage	Jefferson	38	15	47.4	85	32	19.2
Anderson	Logan	37	01	06.6	86	47	54.5
Avenstoke	Anderson	38	06	29.2	85	00	01.4
Avoca	Jefferson	38	15	22.1	85	30	01.0
Bagdad	Shelby	38	15	43.2	85	03	23.9
Beechwood	Owen	38	23	38.9	84	43	15.3
Belcourt	Webster	37	31	54.4	87	28	40.4
Benson	Franklin	38	12	25.2	84	57	37.2
Blackford	Webster	37	27	02.6	87	56	04.1
Blanchet	Grant	38	31	10.3	84	34	18.4
Brandy Keg	Floyd	37	40	26.05	82	40	57.23
Brashear	Perry	37	06	13.26	83	08	41.065
Breck	Owen	38	29	19.1	84	44	14.6
Brooks	Bullitt	38	03	39.3	85	42	37.8
Brownsboro	Oldham	38	21	27.9	85	30	00.4
Canada	Pike	37	35	45.62	82	21	39.16
Caneyville	Grayson	37	25	47.2	86	29	03.8
Cartwright	Clinton	36	45	05.0	85	04	46.7
Cleopatra	McLean	37	37	23.9	87	17	36.9
Clyde	Wayne	36	53	56.3	84	59	38.5
Cooper	Wayne	36	46	16.8	84	51	44.6
Coopersville	Wayne	36	45	46.5	84	43	52.2
Corinth	Grant	38	29	39.9	84	33	42.5
Cordyon	Henderson	37	44	50.1	87	41	51.3
Cox Knob	Jefferson	38	09	25.4	85	46	15.8
Creswell	Caldwell	37	16	13.3	87	54	40.6
Dalton	Hopkins	37	17	49.7	87	45	55.6
Davenport	Butler	37	10	59.3	86	42	59.7
Decker	Butler	37	20	10.0	86	29	01.0
Dell	Russell	36	57	55.3	84	52	26.0
Diamond Springs	Logan	37	02	08.6	86	58	26.4
Dick	Pike	37	30	04.42	82	13	39.68
Dixie	Henderson	37	44	08.4	87	42	03.0
Donerail	Fayette	38	08	58.7	84	32	09.8
Dundee	Ohio	37	33	32.6	86	46	19.3
Duvall	Scott	38	14	49.3	84	38	27.6
East Eagle	Owen	38	26	54.2	84	45	30.9
Elk Chester	Fayette	38	04	18.4	84	37	09.0
Elkhorn Station	Franklin	38	13	08.6	84	47	58.6
Elmville	Franklin	38	20	28.3	84	45	40.8
Enon	Caldwell	37	15	34.1	87	58	43.9

ASTRONOMICAL STATIONS IN KENTUCKY—Continued.

Place.	County	Latitude			Longitude		
Euterpe	Henderson	37	42	59.1	87	26	34.6
Fairbanks	Owen	38	25	58.5	84	43	57.3
Falmouth	Pendleton	38	40	37.6	84	16	54.2
Flournoy	Union	37	41	53.7	87	51	36.0
Frankfort	Franklin	38	11	59.7	84	52	38.8
Free Union	Webster	37	31	29.4	87	45	43.1
Georgetown	Scott	38	12	27.5	84	32	53.5
Gladstone	Crittenden	37	25	46.6	87	58	06.0
Glenville	McLean	37	35	43.8	87	11	29.1
Gratz	Owen	38	28	24.6	84	57	14.1
Greensboro	Anderson	38	00	16.1	85	03	35.5
Greensburg	Green	37	15	38.3	85	29	56.4
Gregory	Wayne	36	49	47.4	84	42	02.9
Grove Center	Union	37	38	29.3	88	00	43.5
Gudgel	Anderson	38	00	34.7	84	59	27.6
Guffie	McLean	37	39	19.3	87	15	11.3
Gum Grove	Union	37	37	00.8	88	00	19.6
Guthrie	Todd	36	38	53.9	87	09	36.15
Harlan	Harlan	36	53	53.76	83	19	04.88
Hartford	Ohio	37	27	07.5	86	54	29.6
Hatton	Shelby	38	13	35.4	85	00	23.6
Haynesville	Ohio	37	39	43.4	86	45	20.3
Hearin	Webster	37	32	07.3	87	50	52.7
Heekin	Grant	38	36	01.5	84	36	52.7
Herman	Union	37	39	10.4	87	45	30.2
Henderson	Henderson	37	50	24.8	87	35	26.1
Hesler	Owen	38	27	48.0	84	46	36.7
Hickman	Fulton	36	34	17.7	89	11	39.0
Highland Park	Jefferson	38	11	15.2	85	45	24.0
Hinton	Grant	38	27	23.4	84	31	49.9
Hood	Crittenden	37	25	23.2	88	00	03.2
Huber	Bullitt	38	01	59.7	85	42	34.2
Jabez	Russell	36	59	14.2	84	53	35.8
Jacksonville	Bourbon	38	16	44.9	85	00	46.0
Jingo	Ohio	37	29	58.7	86	48	26.4
Kinkaid	Scott	38	16	25.2	84	32	55.1
Laffoon	Daviess	37	38	26.0	86	56	30.8
Lakeland	Jefferson	38	16	10.8	85	33	16.2
Lawrenceburg	Anderson	38	02	07.2	84	53	37.4
Lawrenceville	Grant	38	34	05.3	84	39	00.2
Lee	Butler	37	17	16.0	86	30	00.1
Lewisburg	Logan	36	59	12.2	86	56	50.1

ASTRONOMICAL STATIONS IN KENTUCKY—Continued.

Place.	County	Latitude			Longitude		
Lexington	Fayette	38	03	14.2	84	30	55.8
Lisman	Webster	37	28	13.5	87	43	45.3
Little Mount	Spencer	38	03	40.1	85	15	05.3
Livermore	McLean	37	29	31.0	87	08	05.5
Lockport	Henry	38	26	12.4	84	57	56.8
London	Laurel	37	08	02.7	84	05	17.54
Longrun	Jefferson	38	13	48.0	85	25	30.0
Louisa	Lawrence	38	06	55.2	82	36	06.2
Louisville	Jefferson	38	15	31.6	85	45	54.77
Love	Butler	37	15	56.8	86	31	36.5
Luzon	Webster	37	32	42.9	87	43	22.1
Lyonia	Hancock	37	42	31.4	86	45	46.7
Marrattay	Spencer	38	02	33.7	85	13	00.6
Mason	Grant	38	34	24.4	84	35	09.3
Middletown	Jefferson	38	14	41.9	85	32	23.1
Milner	Woodford	38	02	01.3	84	48	28.7
Mill Springs	Wayne	36	55	59.9	84	46	43.8
Morgantown	Butler	37	13	44.0	86	41	17.7
No Creek	Ohio	37	28	58.0	86	57	10.4
Nuckols	McLean	37	31	26.0	87	06	54.6
Oakland	Warren	37	02	27.5	86	15	19.4
O'Bannon	Jefferson	38	17	18.8	85	30	48.0
Oil Valley	Wayne	36	46	31.8	84	48	05.4
Ono	Russell	36	59	21.2	84	57	59.4
Owensboro	Daviess	37	46	01.5	87	06	40.5
Paducah	McCracken	37	04	52.2	88	35	56.1
Payne	Fayette	38	03	28.7	84	33	39.0
Pellville	Hancock	37	45	13.8	86	48	32.0
Pewee Valley	Oldham	38	18	31.8	85	29	22.1
Philpot	Daviess	37	43	47.9	86	58	48.4
Post	Grayson	37	29	03.5	86	26	24.6
Providence	Webster	37	23	57.9	87	45	41.5
Quinn	Caldwell	37	17	43.6	87	50	07.9
Repton	Crittenden	37	23	24.8	88	00	56.0
Reynolds Sta.	Ohio	37	39	43.4	86	45	46.6
Richardsville	Warren	37	06	17.7	86	28	08.5
Richlieu	Logan	37	00	17.7	86	41	24.7
Richmond	Madison	37	44	39.6	84	17	51.2
Rogers Gap	Scott	38	18	14.4	84	32	15.5
Sadieville	Scott	38	23	28.1	84	32	11.4
Shelbyville	Shelby	38	12	39.2	85	12	57.1
Shepherdsville	Bullitt	37	59	16.6	85	42	59.9

ASTRONOMICAL STATIONS IN KENTUCKY—Continued.

Place.	County	Latitude			Longitude		
Simpsonville	Shelby	38	13	20.8	85	21	33.4
Slaughterville	Webster	37	29	26.4	87	30	00.9
Smithville	Bullitt	38	00	46.2	85	30	52.4
Stamping Ground	Scott	38	16	13.6	84	41	11.3
Starr	Crittenden	37	17	36.0	88	00	10.2
Steubenville	Wayne	36	53	16.3	84	48	08.6
St. Mathews	Jefferson	38	15	10.2	85	39	37.0
St. Vincent	Union	37	42	22.8	87	50	21.3
Sturgis	Union	37	32	48.5	87	59	03.6
Sullivan	Union	37	29	58.8	87	56	37.1
Sulphur Springs	Ohio	37	32	10.9	86	46	33.4
Susie	Wayne	36	47	49.2	84	57	55.8
Switzer	Franklin	38	15	10.1	84	45	25.3
Taylorsville	Spencer	38	01	51.0	85	20	41.8
Threlkel	Butler	37	11	28.0	86	29	47.6
Tilden	Webster	37	36	20.2	87	42	40.0
Tousey	Grayson	37	30	52.0	86	32	34.1
Tribune	Crittenden	37	20	56.8	87	59	26.0
Tyrone	Anderson	38	02	11.7	84	51	01.9
Uniontown	Union	37	46	14.6	87	56	16.6
Utica	Daviess	37	36	16.2	87	06	49.9
Vanderburg	Webster	37	29	19.5	87	38	31.8
Van Meter	Fayette	38	03	38.0	84	35	23.0
Versailles	Woodford	38	03	23.9	84	43	50.8
Wait	Wayne	36	46	11.5	84	59	13.2
Waterford	Spencer	38	02	20.3	85	26	13.9
Waverly	Union	37	42	21.3	87	48	41.0
Westerfield	Ohio	37	35	41.9	86	55	39.4
West Point	Hardin	37	59	52.7	85	56	58.8
Westport	Oldham	38	28	46.46	85	28	25.93
Whitfield	Bullitt	38	05	35.5	85	28	31.8
Williamstown	Grant	38	38	12.5	84	33	39.4
Wilson	Henderson	37	46	52.4	87	39	19.6
Yeaman	Grayson	37	31	08.1	86	34	33.6
Zula	Wayne	36	46	18.7	84	58	52.8